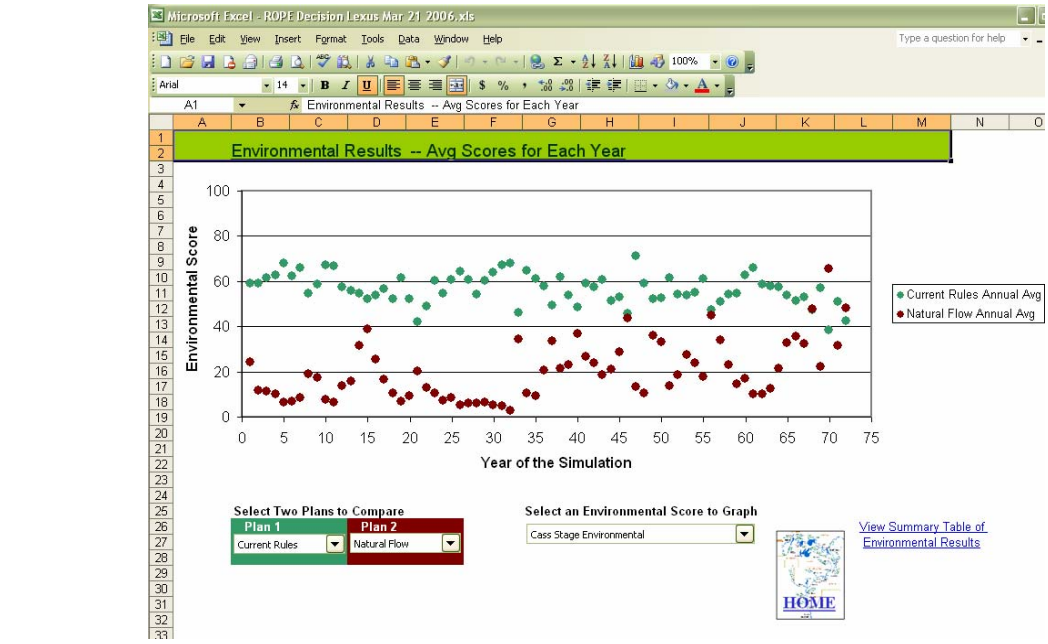
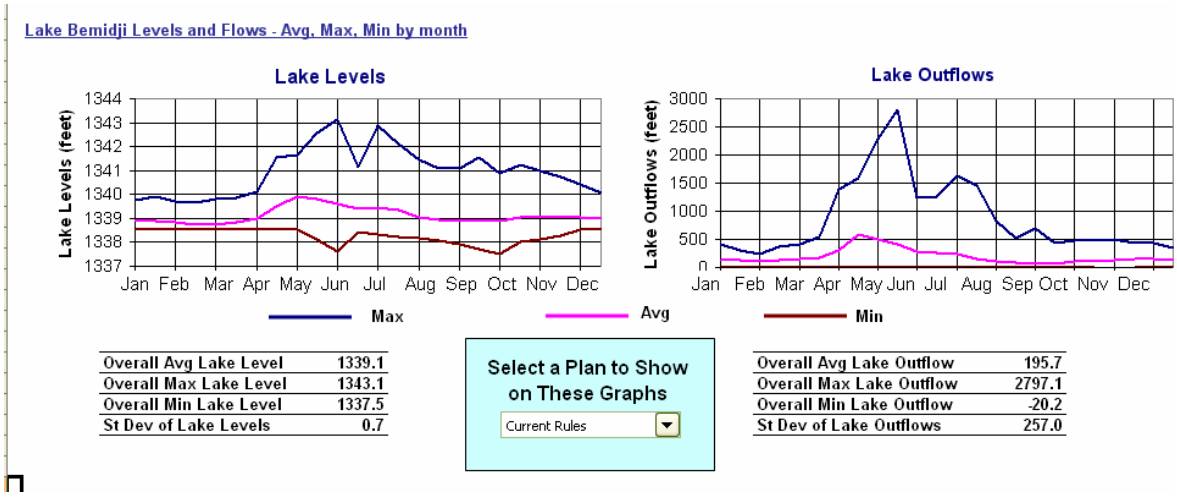
# A Short Guide on Interactive Decision Support Tools Using Microsoft Excel




**Institute for Water Resources**

Mark Lorie
Water Resources Planner
(703) 428 – 7245
Mark.A.Lorie@usace.army.mil

Hal Cardwell, Ph.D.
Senior Policy Analyst
(703) 428 – 9071
Hal.E.Cardwell@usace.army.mil

April 2006 IWR Report 06-R-2

# Table of Contents

## Section 1: Introduction and Background



## Section 2: Creating a Decision Support Tool



## Section 3: Tutorials

# Figures



# Tables

# Section 1: Introduction and Background

## *1.1 Purpose of this Guide*

This Guide is intended to provide an introduction and overview of how Microsoft Excel can be used to create dynamic decision support tools for Corps planning studies. It is based on practical experience in two on-going water management studies. The techniques covered in this Guide are focused on analyzing and exploring the technical and scientific results of Corps studies. The Guide does not offer any policy or procedural suggestions and it does not supersede existing Corps planning guidance. Several of the techniques discussed in this Guide are used for analyzing or displaying tradeoffs, but it is not meant to suggest methods for actually calculating tradeoffs. In general, the tools described in this guide should be used in support of existing Corps guidance on planning and decision-making.

Five different features that can be used to create decision support tools in Excel are covered here. They include:

- Enhancing data tables with automatic formatting options;
- Graphs and charts;
- Using forms to make tables, graphs and charts dynamic;
- Embedding documents and slides;
- Using hyperlinks to facilitate navigation.

## *1.2 Excel as a Decision Support Tool*

Most water resources professionals make use of Microsoft Excel in performing their work. Typical applications include basic computations, data storage or manipulation, tables for organizing text, and producing graphical displays of various kinds of data. For example, Excel is often used to track study budgets, including adding up expenditures and graphing budget allocations in pie charts. In addition, Excel is frequently used for analyzing scientific data needed for planning studies or for producing customized graphs to be used in presentations or study reports.

In two on-going collaborative planning studies, Excel has been used in a much more extensive manner (for more information on these studies visit the following website: www.iwr.usace.army.mil/iwr/svp/home/htm). These two collaborative planning efforts are focused on developing new reservoir operation plans to better address environmental, recreational or other emerging objectives. One study is focused on a dam controlling outflows from Lake Ontario and the other is on the Mississippi River headwaters system. In each case, a computer model simulates reservoir operations over some period of time and calculates the resulting levels and flows throughout the system being modeled. A primary goal of each study is to integrate all the technical analysis needed for plan formulation and evaluation in one tool, so

the computer model in each study also calculates the various economic and environmental impacts of simulated reservoir operations (e.g., expected flood damages, recreational benefits).

In each of these two studies, Excel was used to build a dynamic decision support tool (DST) that integrates the modeling results and allows for interactive graphs and other displays. These DSTs developed in Excel have proven to be very useful in each of these studies and similar tools could probably be useful for other Corps planning studies. The model in each of these two studies generates enormous amounts of information. In the case of the Lake Ontario model, the simulation is 101 years long with a quarter-monthly time step and it includes dozens of hydraulic calculations (levels and flows) and performance measures (economic and environmental impacts). For each alternative that is considered, this results in 4848 data points (101 years times 48 quarter-months per year) for several dozen variables. The Mississippi Headwaters model produces a similar amount of information. In each case, a tool was needed to allow diverse stakeholders and decision-makers the opportunity to explore these results.

## *1.3 Purpose and Structure of the Excel Decision Support Tool (DST)*

In each study described above, the Excel DST was merely a post processor of output data from other models[1]. All of the hydraulic, economic, environmental and other impacts were calculated in other models developed for each study. The DSTs included few original calculations. The role of these DSTs is to "slice and dice" the output data in order to produce graphs, tables and other displays of the data for purposes of comparison, evaluation and plan selection. The basic format used resembles a typical database application. Some worksheets within the Excel DST contain the raw model output data for each alternative while other worksheets serve as graphical interfaces. These interfaces allow users to select, manipulate and display the raw data based on options selected by the user in various drop down menus, option buttons and other controls. Users include technical analysts fine tuning plan formulation, stakeholders exploring impacts to their interest and decision-makers exploring tradeoffs.

These DSTs are usually constructed so that users start with general summaries of results and drill down into detailed displays of results. The tool guides users to graphs, charts or tables of summary, aggregated statistics first. From there, a user finds links to more and more specific information. For example, a user might start with displays of net economic impacts, overall environmental quality measures, or other aggregated results. Then they might navigate (usually using hyperlinks, which are described in detail later in this Guide) to displays of the economic impacts to specific sectors or geographic regions, or the environmental impacts to particular ecosystems or locations. This kind of hierarchical structure facilitates organized learning about the results and helps prevent data overload.

The visual and interactive nature of these DSTs makes them excellent tools for use during various kinds meetings and workshops. In the Lake Ontario case mentioned earlier, the Excel tools were frequently shown on a projection screen during stakeholder workshops, public meetings and during decision-maker deliberations. One of the designers of the tool served as a

[1] Planning Models used in Corps studies need to be certified under EC-407. Since DSTs are not intended to perform any original calculations, they usually will not need any review under EC-407. If a DST is designed with some original calculations then it will require at least some level of review.

facilitator and responded to questions from the meeting participants using the DST. For example, if a participant asked to see how the alternatives compare in their performance during droughts, the facilitator would bring up various displays in the DST relevant to that question. Using these tools in a live setting like this promotes productive discussions and learning among the players in a planning study.

## *1.4 The Benefits of Excel for Collaborative Decision Support*

***1. DSTs provide easy-to-use data visualizations***. It's no secret that graphical presentations of data make interpretation much easier and most Corps planning reports include graphs to display study results. Excel comes with a number of graphing options, most of which are familiar to many people. Furthermore, Excel's graphs can be customized in many ways and these features can be used to communicate even more information in a visual manner. Specific examples of different graphs and how to customize them are presented in section 2.2. In addition to graphing capabilities, automatic formatting within Excel can make basic data tables communicate information more easily. This kind of automatic formatting is covered in section 2.1.

***2. DSTs allow stakeholders and decision-makers to view results across multiple objectives and impacts together in one interactive tool.*** Planning within the Corps is becoming more and more of a collaborative practice, and that is now embodied in Corps policy (i.e., EC 1105-2-409, "Planning in a Collaborative Environment"). Corps planners already must collaborate extensively with a project's non-federal sponsor and they increasingly collaborate with other interested stakeholders (other agencies, environmental groups and impacted stakeholders). The ability to show data on project impacts across multiple objectives (e.g., habitat restoration, flood protection, water supply storage) in one tool can help foster a collaborative process within planning studies. Stakeholders can quickly and easily see the impacts of alternatives to their interest(s) and to other interests, which can help competing stakeholders learn more about the tradeoffs presented by the available alternatives. These Excel DSTs can be used in meetings and workshops to facilitate discussions about plan formulation and evaluation.

***3. DSTs can include various interactive features, which promotes learning and understanding.*** These features might include drop down menus or option buttons (described in more detail in the sections below). Interactive features make the graphical displays more dynamic—e.g., the user can select which alternatives to compare on a particular graph using a drop down menu. Therefore, users can interact with the data extensively—a user can make quick comparisons between alternatives or conduct sensitivity analysis on certain parameters. This kind of interaction promotes learning and discovery. With so much information produced by the simulation models, the risk with allowing such extensive interaction with the data is that users might become overwhelmed. The fact that the DSTs are designed to facilitate a "drill down" approach to exploring the data helps prevent data overload. Results are presented in various levels of detail so that the user can start with broad summaries and "drill

***4. Excel is ubiquitous and familiar to most Corps planners.*** Of course, all of these features can be incorporated into a decision support tool based on another software package. For example, it is possible to design and build a decision-support tool from scratch using Visual Basic or some other sophisticated programming language. Such a tool could be designed with any features

desired and would be very flexible. However, there are some drawbacks to this approach. First, it could be much more expensive compared to developing an Excel DST because it would require more time. In addition, a customized tool would most likely require a consultant to do the programming. While Corps planners are accustomed to working with consultants, one of the purposes of the tools described here is to have a flexible tool that could be modified quickly (e.g., during the course of a workshop). That might not be possible with a tool programmed by an outside consultant. Finally, the intent is to use these tools as part of a collaborative planning effort. Most people have Excel on their computer and many would be quite familiar with how to use Excel. This would allow a number of people to work on developing the DST.

## *1.5 Organization of this Guide*

This Guide is intended to provide summaries of some of the capabilities in Microsoft Excel that can help planners to create a tool that is dynamic and useful for facilitating learning among stakeholders. The Guide is not exhaustive—many features in Excel are not described here, such as the use of Macros. The features presented here are the ones that were used most in previous studies and that proved to be most useful; other features may be more useful in other contexts. Readers can learn about additional Excel features not covered here by exploring sample DSTs (provided on CD with this report; see below) and by experimenting with different features themselves.

Section 2 of this guide summarizes several features in Excel that are really essential for developing dynamic DSTs. The functionality of these features and the benefits they offer as part of the DSTs are described. Tutorials on how to implement these features are presented in Section 3. This Guide will be available from IWR on CD and that CD will also include sample versions of the DSTs referenced here. These are fully functional samples and can be copied to any computer. These samples should provide some hands on learning opportunities to see exactly how Excel DSTs are organized and how they function. Table 1.1 summarizes the sample DSTs. In addition, readers can contact the IWR authors of this Guide with specific questions or concerns (contact information is shown on the cover page).

**Table 1.1: DSTs Provided with this Guide**

| DST | Originating Study | Description |
|---|---|---|
| Board Room.xls | Lake Ontario Study | This is a version of the full DST for the Lake Ontario study. It contains several real plans formulated and evaluated for that study, many evaluation metrics and dozens of visual displays. This DST is very big and may be slow on some computers. |
| Suggested Criteria Eval.xls | Lake Ontario Study | This was a preliminary DST created to engage stakeholders in discussions about desired levels and flows within the Lake Ontario Basin. |
| ROPE Decision Lexus.xls | Mississippi Headwaters Study | This is a preliminary version of the full DST for the Mississippi Headwaters study. It contains only a few plans, many evaluation metrics and several visual displays. |

# Section 2: Creating a Decision Support Tool

## *2.1 Enhancing Data Tables*

Tables are probably the simplest way to present study results. They can also be one of the least communicative ways to present results, especially in complex planning studies. If there are a small number performance measures and alternatives, then a simple, basic table is probably sufficient. For example, suppose Table 2.1 represents results for three operational alternatives in a section 216 study. Since there are only three alternatives and two performance measures, it is relatively easy to grasp the tradeoffs represented in this table.

**Table 2.1: A Simple Data Table**

| | Alternative A | Alternative B | Alternative C |
|---|---|---|---|
| Habitat for Species X (Acres) | 127 | 109 | 140 |
| Expected Annual Flood Damages ($) | 365,400 | 211,900 | 550,400 |

It is rare that a decision could be based on such simple results. Table 2.2 presents a more complicated case in which the tradeoffs are not so readily apparent. Even the results represented in Table 2.2 are probably more simplistic than the results of typical Corps study.

**Table 2.2: A Bigger Data Table**

| | Alternatives | | | | |
|---|---|---|---|---|---|
| | A | B | C | D | E |
| Habitat (Acres) | 127 | 109 | 140 | 87 | 144 |
| Risk to Archeological Sites | .04 | .06 | .04 | .00 | .08 |
| Expected Annual Flood Damage ($) | 365,400 | 211,900 | 550,400 | 204,200 | 765,800 |
| Recreation Benefits ($) | 180,500 | 171,200 | 144,000 | 133,000 | 96,300 |
| Water Supply Reliability | .99 | .98 | .99 | .96 | .98 |
| Hydropower Capacity (MW) | 278 | 269 | 281 | 255 | 304 |

Complex tables such as Table 2.2 can be enhanced with colors and other formatting options. For example, Table 2 2.is recreated below as Table 2.3 but with some new features. For each metric, the result of the best alternative is highlighted green while the worst is highlighted red.

**Table 2.3: A Data Table with Additional Visual Cues**

| | Alternatives | | | | |
|---|---|---|---|---|---|
| | A | B | C | D | E |
| Habitat (Acres) | 127 | 109 | 140 | 87 | 144 |
| Risk to Archeological Sites | .04 | .06 | .04 | .00 | .08 |
| Expected Annual Flood Damage ($) | 365,400 | 211,900 | 550,400 | 204,200 | 765,800 |
| Recreation Benefits ($) | 180,500 | 171,200 | 144,000 | 133,000 | 96,300 |
| Water Supply Reliability | .99 | .98 | .98 | .96 | .98 |
| Hydropower Capacity (MW) | 278 | 269 | 281 | 255 | 304 |

With the shaded cells indicating the best and worst results on each objective, the table communicates key information more effectively. Alternative E is the best for habitat and hydropower, but the worst for three other measures. Alternative A is the best for recreation and water supply, and it is not the worst plan for any measure. These kinds of insights help planners, stakeholders and decision-makers understand the data more easily.

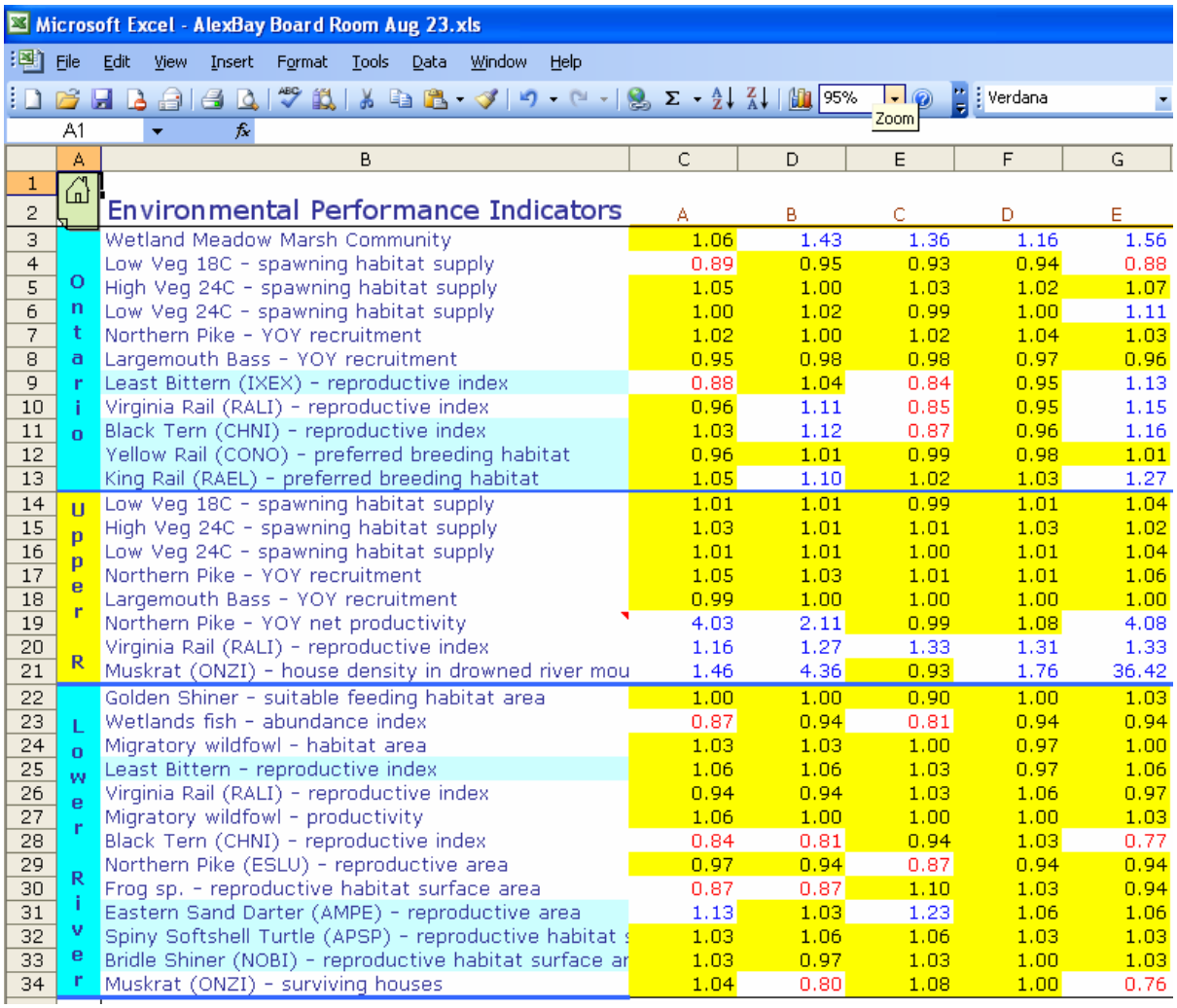
When used as part of a DST, formatting options within Excel can be set up to work automatically based on the values that appear in a table. This can be done with the ***Conditional Formatting*** feature in Excel. Automatic formatting can be useful for several reasons. First, automatic formatting will respond to changes in data. Recall that these DSTs contain worksheets of raw data and that all the visual features pull from that raw data. Sometimes, it may be necessary to change the raw data (i.e., one of the source models is changed and all the alternatives are re-run). Also, it may be useful to make the table dynamic—i.e., the data shown in the table changes depending on options selected by the user (tools for allowing user options are discussed in section 2.3). Conditional formatting will change automatically in response to both of these situations.

The conditional formatting feature appears under the 'Format' menu in Excel. It works using basic "if-then" logic. You're allowed to choose which cell value triggers the formatting, the type of condition, the argument for the condition, and the resulting format for that cell. For example, using Table 2.2, you can create a conditional formatting option that accomplishes the following: if the habitat score under an alternative is greater than 100, then highlight the cell for that alternative green. ***Tutorial 1 in Section 3 provides screen captures from Excel to show you how to use conditional formatting.***

There are a variety of ways to use conditional formatting to communicate more information than just the numbers themselves. Conditional formatting can be used to

- communicate which plan is the best on each metric;
- communicate which plan is the worst on each metric; and
- show which plans score above or below on several thresholds.

In addition to highlighting patterns in the data, formatting options in Excel can also be used to visually organize the contents of table. Cell shading, different fonts, and borders can all help distinguish different categories of results and make a table easier to read. The example in Figure 1 will be used to demonstrate both conditional formatting and the use of formatting options for visually organizing a data table.



Microsoft Excel - AlexBay Board Room Aug 23.xls

File Edit View Insert Format Tools Data Window Help

95% Zoom Verdana

A1

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | Environmental Performance Indicators | A | B | C | D | E |
| 3 | Ontario | Wetland Meadow Marsh Community | 1.06 | 1.43 | 1.36 | 1.16 | 1.56 |
| 4 | | Low Veg 18C - spawning habitat supply | 0.89 | 0.95 | 0.93 | 0.94 | 0.88 |
| 5 | | High Veg 24C - spawning habitat supply | 1.05 | 1.00 | 1.03 | 1.02 | 1.07 |
| 6 | | Low Veg 24C - spawning habitat supply | 1.00 | 1.02 | 0.99 | 1.00 | 1.11 |
| 7 | | Northern Pike - YOY recruitment | 1.02 | 1.00 | 1.02 | 1.04 | 1.03 |
| 8 | | Largemouth Bass - YOY recruitment | 0.95 | 0.98 | 0.98 | 0.97 | 0.96 |
| 9 | | Least Bittern (IXEX) - reproductive index | 0.88 | 1.04 | 0.84 | 0.95 | 1.13 |
| 10 | | Virginia Rail (RALI) - reproductive index | 0.96 | 1.11 | 0.85 | 0.95 | 1.15 |
| 11 | | Black Tern (CHNI) - reproductive index | 1.03 | 1.12 | 0.87 | 0.96 | 1.16 |
| 12 | | Yellow Rail (CONO) - preferred breeding habitat | 0.96 | 1.01 | 0.99 | 0.98 | 1.01 |
| 13 | | King Rail (RAEL) - preferred breeding habitat | 1.05 | 1.10 | 1.02 | 1.03 | 1.27 |
| 14 | Upper R | Low Veg 18C - spawning habitat supply | 1.01 | 1.01 | 0.99 | 1.01 | 1.04 |
| 15 | | High Veg 24C - spawning habitat supply | 1.03 | 1.01 | 1.01 | 1.03 | 1.02 |
| 16 | | Low Veg 24C - spawning habitat supply | 1.01 | 1.01 | 1.00 | 1.01 | 1.04 |
| 17 | | Northern Pike - YOY recruitment | 1.05 | 1.03 | 1.01 | 1.01 | 1.06 |
| 18 | | Largemouth Bass - YOY recruitment | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |
| 19 | | Northern Pike - YOY net productivity | 4.03 | 2.11 | 0.99 | 1.08 | 4.08 |
| 20 | | Virginia Rail (RALI) - reproductive index | 1.16 | 1.27 | 1.33 | 1.31 | 1.33 |
| 21 | | Muskrat (ONZI) - house density in drowned river mou | 1.46 | 4.36 | 0.93 | 1.76 | 36.42 |
| 22 | Lower River | Golden Shiner - suitable feeding habitat area | 1.00 | 1.00 | 0.90 | 1.00 | 1.03 |
| 23 | | Wetlands fish - abundance index | 0.87 | 0.94 | 0.81 | 0.94 | 0.94 |
| 24 | | Migratory wildfowl - habitat area | 1.03 | 1.03 | 1.00 | 0.97 | 1.00 |
| 25 | | Least Bittern - reproductive index | 1.06 | 1.06 | 1.03 | 0.97 | 1.06 |
| 26 | | Virginia Rail (RALI) - reproductive index | 0.94 | 0.94 | 1.03 | 1.06 | 0.97 |
| 27 | | Migratory wildfowl - productivity | 1.06 | 1.00 | 1.00 | 1.00 | 1.03 |
| 28 | | Black Tern (CHNI) - reproductive index | 0.84 | 0.81 | 0.94 | 1.03 | 0.77 |
| 29 | | Northern Pike (ESLU) - reproductive area | 0.97 | 0.94 | 0.87 | 0.94 | 0.94 |
| 30 | | Frog sp. - reproductive habitat surface area | 0.87 | 0.87 | 1.10 | 1.03 | 0.94 |
| 31 | | Eastern Sand Darter (AMPE) - reproductive area | 1.13 | 1.03 | 1.23 | 1.06 | 1.06 |
| 32 | | Spiny Softshell Turtle (APSP) - reproductive habitat s | 1.03 | 1.06 | 1.06 | 1.03 | 1.03 |
| 33 | | Bridle Shiner (NOBI) - reproductive habitat surface ar | 1.03 | 0.97 | 1.03 | 1.00 | 1.03 |
| 34 | | Muskrat (ONZI) - surviving houses | 1.04 | 0.80 | 1.08 | 1.00 | 0.76 |

**Figure 2.1: Excel Table of Environmental Scores**

The Excel table in Figure 2.1 shows the scores for five reservoir operation alternatives (A-E) against a number of environmental metrics. The cells containing the actual data show three different formats in various places: yellow shading (white shading is the default formatting), blue font and red font. The scores represent an alternative's performance relative to the baseline plan or status quo (i.e., the plan that is in place now). Detailed description of where the numbers come from is beyond the scope of this guide, but in general the interpretation can be summarized as follows:

| | |
|---|---|
| Metric Greater than 1 | Better performance than the baseline plan |
| Metric equal to 1 | Equal performance with the baseline plan |
| Metric less than 1 | Worse performance than the baseline plan |

Conditional formatting was utilized to visually demonstrate which plans are clearly better than the baseline plan, which are clearly worse and which are too close to call. The environmental experts involved with the study decided, as a rule of thumb, that scores between .9 and 1.1 were too close to call—performance was close enough to the baseline plan that they should be considered equivalent. Therefore, three formats were applied: 1) scores between .9 and 1.1 result in the cell being shaded yellow, otherwise the cell remains shaded white; 2) scores that are greater than 1.1 get blue font; and 3) scores that are less than .9 get red font. A guide to these scores can be included next to the table if there is room, or in an embedded file (Word document or PowerPoint slideshow) that can be accessed directly from the DST (embedding files is covered in section 2.4).

In addition to the conditional formatting based on the environmental scores, this table contains other formatting features to help organize its contents. This table was taken from the Lake Ontario study DST. There are three regions covered by that study (Lake Ontario, the Upper River, and the Lower River) and the environmental metrics associated with each region in the table are labeled along the left side and given a different color shading to visually distinguish them. In addition, the three regions are separated by a thick blue border. Also, eight of these metrics are associated with threatened or endangered species. In order to make those stand out visually, the rows containing those metrics are given light blue shading.

The formatting used in this table quickly communicates how the plans perform against the environmental metrics and how they compare with each other. Most of the table is shaded yellow which clearly shows that most of the environmental metrics are not affected by the alternative plans when compared to the baseline plan. Plan D doesn't have any red metrics, which means it does as well or better than the baseline plan on all the environmental metrics. Plans A and C have several red metrics and fewer blue metrics, which might mean that they do more overall harm than good. Plans B and E show the opposite pattern, so maybe they do more good than harm. Both Plans A and C have red scores for at least one of the threatened or endangered species, which might be considered unacceptable. Planners, stakeholders and decision-makers still have to interpret these results, but having good visualization is a way to facilitate the necessary learning.

## ***2.2 Graphs and Charts***

Graphs and charts are another way to visualize study results. Most Corps study reports incorporate various graphs and charts. The intent here is to describe a variety of graphs available in Excel, show how they can be customized to enhance their use as visualization tools, and demonstrate how Excel graphs can be used as part of a dynamic DST.

The primary Excel graphs that have been used in the cases discussed earlier include bar graphs, line graphs, scatter diagrams, and radar diagrams (there are other graph types in Excel,

but they will not be discussed here). Although most Corps planners are probably familiar with these graphs and how to create them in Excel, the next sections briefly summarize each.

## Bar Graphs

Bar graphs are a clear and easy tool to use. They can show multiple objectives or measures and multiple alternatives. Their visual impact can be high depending on the scale of each metric. If the metrics are close enough in value (i.e., they have similar scales), it will be easy compare across objectives and alternatives. If one metric has a huge scale (say, millions of dollars) and others have a small scale (say, acres of habit) then the visual impact is reduced because the bars for the smaller scale metric are barely visible, as in Figure 2.2, in which the habitat score bars are so small that they do not show (but the numbers do).

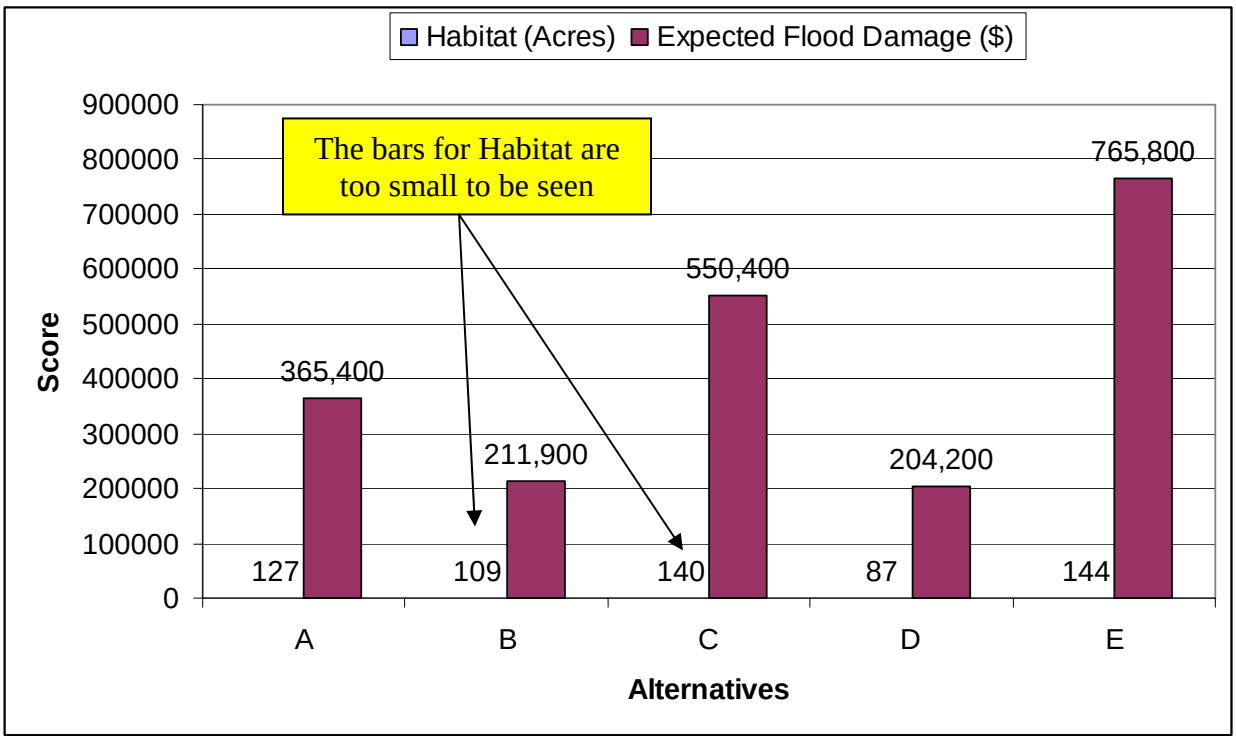



**Figure 2.2: Graph of Hypothetical Data Shown in Table 1**

One way to handle this problem on a bar graph is to re-scale the bigger metric so that the units are similar to the other metric. In this case, expressing the dollar metric in $1000s rather than $1 units improves the graph, as in Figure 2.3.

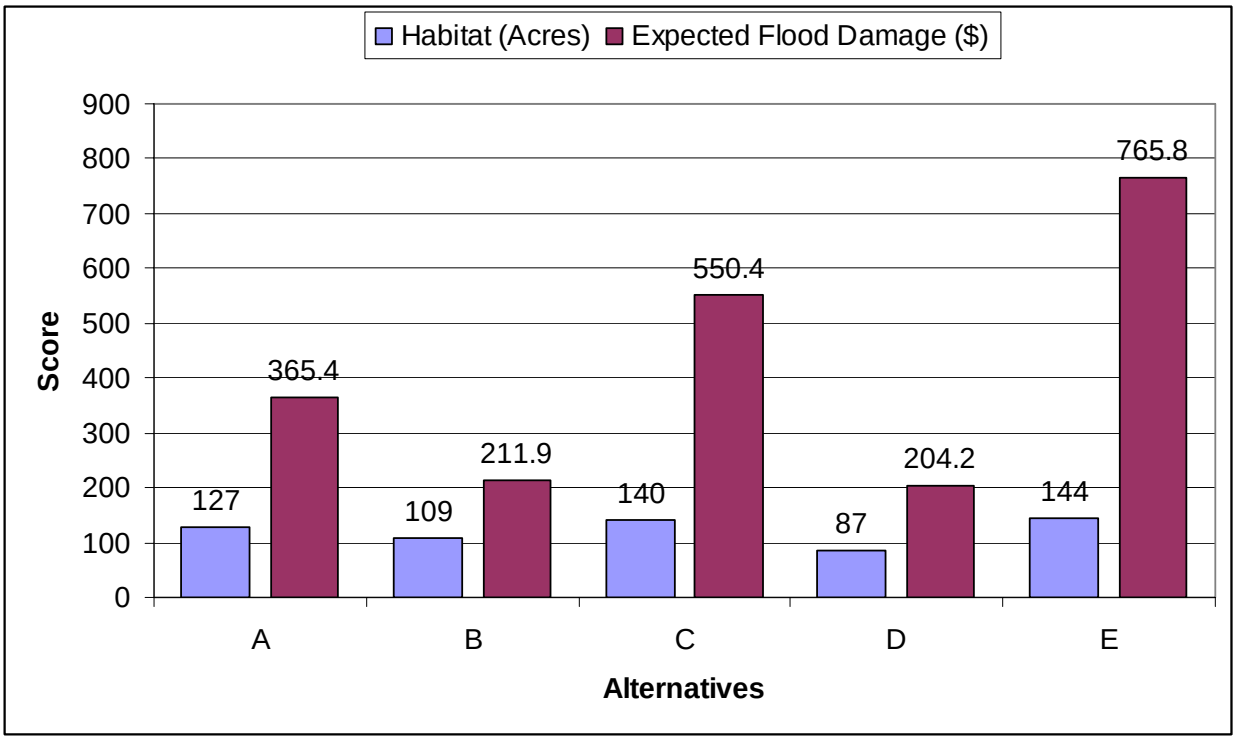



**Figure 2.3: A Bar Graph with Re-Scaled Metrics**

## Line Graphs

Line graphs have typically been used in DSTs for two things: 1) to show time series (results over time) and 2) to construct tradeoff curves.

**Time Series** Time series graphs show the values of a metric over time. A hydrograph is a typical example that will be familiar to many Corps planners. Figure 2.4 shows a hydrograph example in which the lake levels that would result from two different dam operation alternatives are graphed for one particular decade.

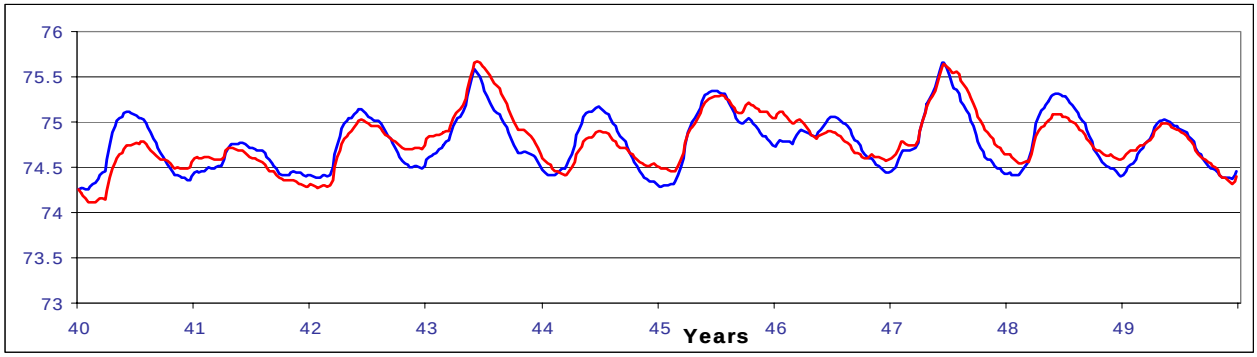



**Figure 2.4: A Hydrograph Comparing Two Alternatives**

Other types of data can be shown on a time series line graph: economic impacts, environmental impacts, reservoir releases, and river flows are a few examples. If the data has a time component (i.e., you have data for each time step), then it can be put on a time series line graph.

Time series line graphs show great detail about study results. For example, they were used frequently in one study to visualize how alternatives perform during known wet periods—i.e., how high alternatives allow Lake Ontario to go during a particularly wet period of the historical record. It addition to specific events, time series line graphs provide a picture of the overall pattern of an alternative. For example, some environmental experts are interested in long-term hydrologic cycles. Time series graphs provided an excellent way to visualize these long term patterns. The time series graphs proved useful both for plan formulation and for the learning process during plan evaluation. Plan formulators could quickly see how well an alternative performs during specific periods and make changes if necessary. Stakeholders and decision-makers would see both performance during specific events (floods) and the broader patterns.

**Tradeoff Graphs** Line graphs can also be used to display the tradeoffs between objectives. This is a very common application in Corps planning studies (e.g., NED-NER tradeoff curves). Tradeoff curves can be constructed with very broad measures, such as NED or NER. They can also be used to show tradeoffs between measures of more specific objectives. For example, the tradeoff between acres of habitat and expected flood damages in a particular reach of a river could be shown on a line graph. Though decision-makers will often have to consider the broader measures, stakeholders (such as cost-share partners or other interests) may want to see more specific information. For example, the NED-NER tradeoff might be important to a District Engineer, but it would not be the most important information for a representative from a particular town within the study region. Figure 2.5 shows an example of a tradeoff curve based on some of the numbers in Table 2.2.

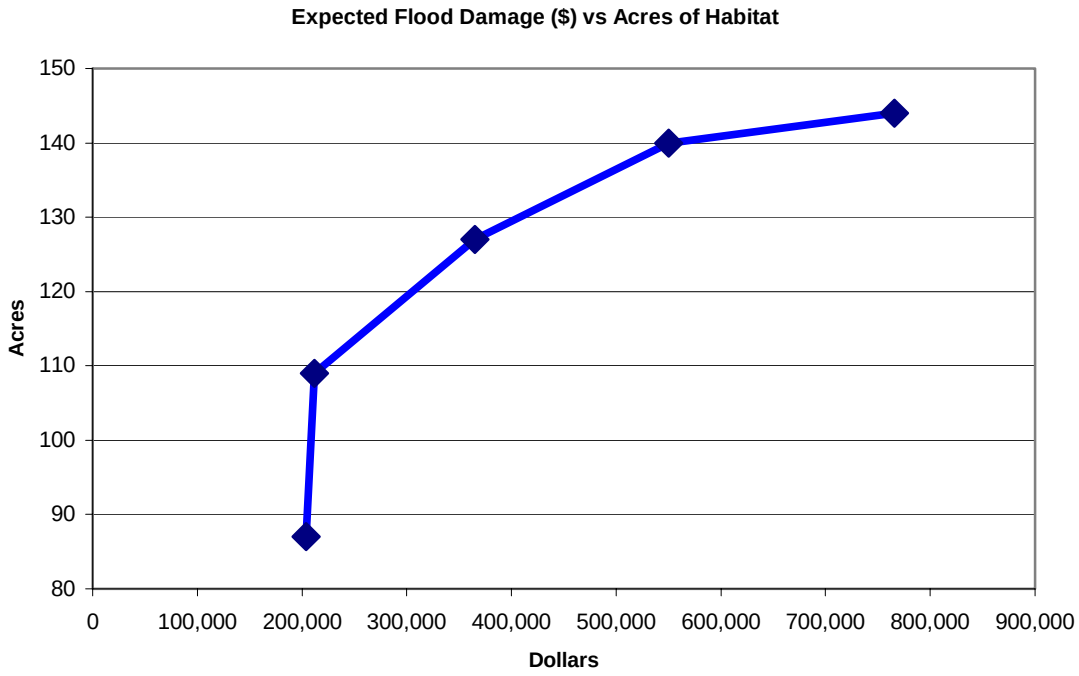


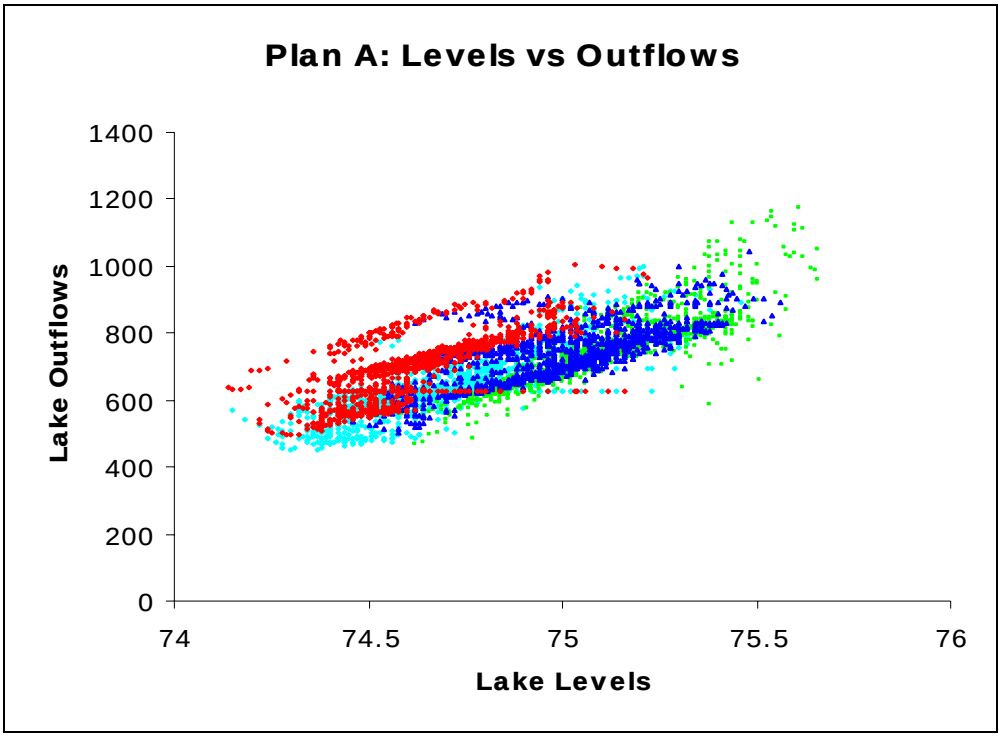

**Figure 2.5: Tradeoff Curves**

## Scatter Diagrams

Scatter diagrams are related to line graphs. Technically, they *are* line graphs without the lines—only the points (diamonds in Figure 2.5) are shown. Typically, they have not been used in the same way as line graphs in the two studies discussed in this report. For the most part, they have been used to compare two measures. Two examples illustrate this.

Figure 2.6 shows a scatter graph that compares Lake Ontario levels and Lake Ontario outflows. In the Lake Ontario study, this graph was characterized as the "footprint" of an alternative. Each point represents the lake level and outflow during one time step of a simulation model run. The different colors represent different seasons (e.g., red points are level-flow combinations that occurred during the summer time steps of the simulation; color customization is covered in tutorial 2). Each graph shows the footprint for a different plan. These were shown side by side in the model to give a quick comparison of the overall pattern of each alternative. As can be seen below, the graphs quickly demonstrate that the two plans have very different overall patterns.

A similar way to use a scatter diagrams is to show performance against multiple objectives on one graph. Figure 2.7 shows a graph that plots one alternative's performance on dozens of metrics.



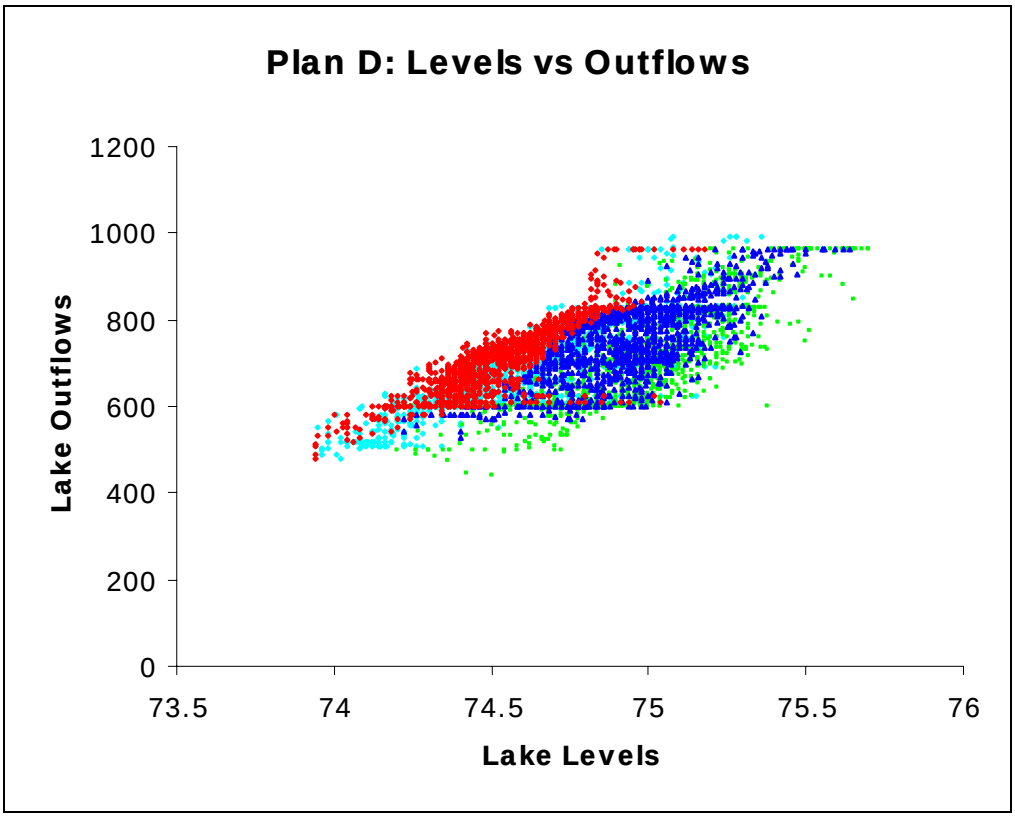




**Figure 2.6: Scatter Diagrams**

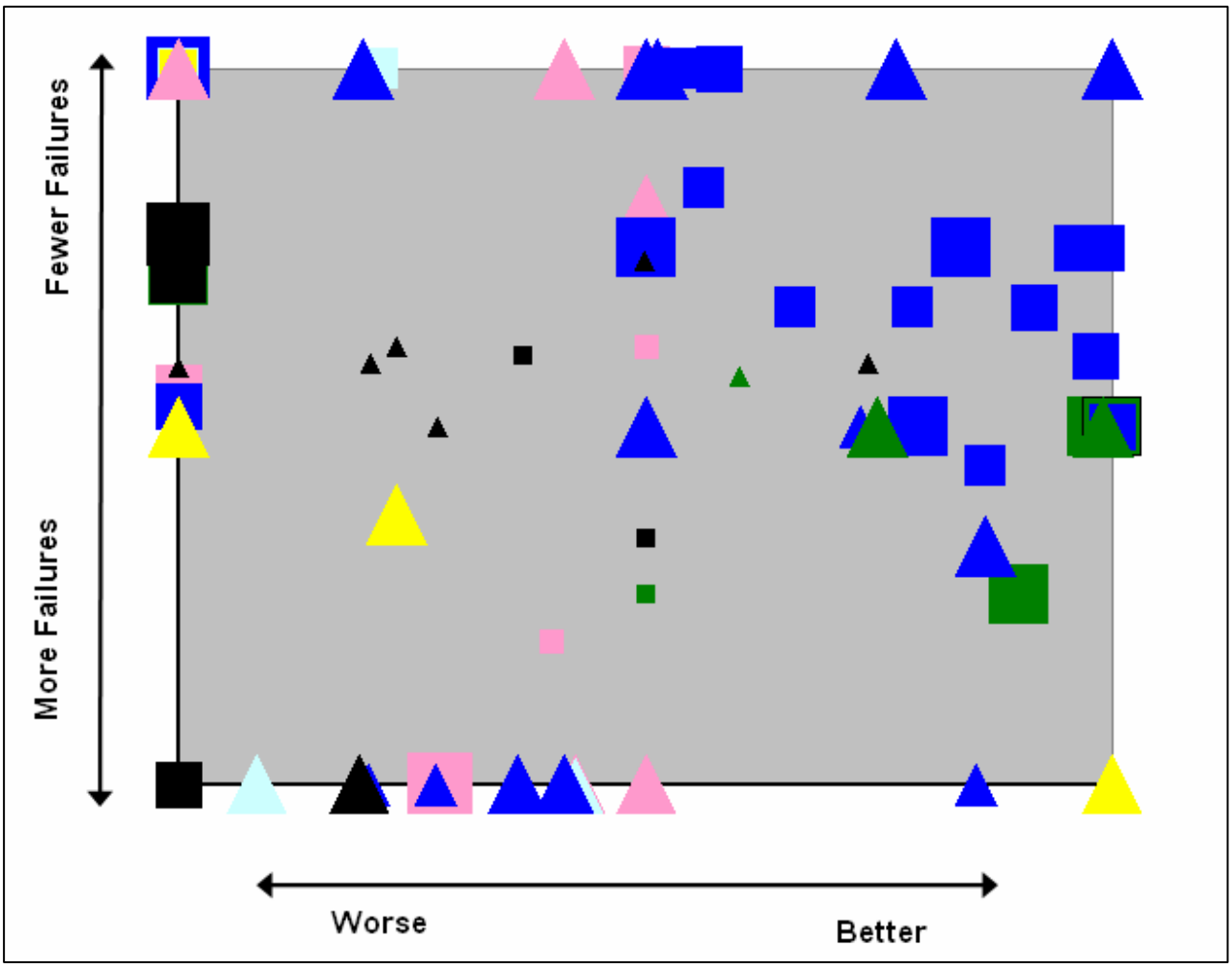



**Figure 2.7: Scatter Diagram with Multiple Objectives**

The graph in Figure 2.7 was also taken from the Lake Ontario study. It is a scatter diagram from an Excel DST with several customized elements. Each point in the diagram represents a plan's performance against water level and flow targets—i.e., how often and how severely a plan exceeds a critical level or flow, such as the flooding stage. The average severity of violations is graphed on the horizontal axis and the average frequency of violations on the vertical axis. Each graph point was customized as follows:

1)The color indicates the stakeholder group (e.g., environmental, recreational boaters etc.) who proposed the target;

2)The size of the graph point indicates the priority of the water level/flow target—big means high priority, small means low priority;
3)The shape of the graph point indicates the location of the water level/flow (above the dam versus below).

This graph contains an enormous amount of information. In addition to the features already discussed, the graph also included some dynamic features, allowing the user to change things such as the plan being displayed (these features will be discussed more in a later section). This graph is not intended to give detailed data on specific targets (there is another graph in the DST for that). Instead, this graph is intended to give decision-makers a summary of multi-objective performance by providing an overview of plan performance against all the targets.

## Radar Diagrams

Radar diagrams are a little less common than the other graphs discussed so far but they are another useful way to summarize performance of alternatives across multiple objectives. Figure 2.8 shows an example of a radar diagram.

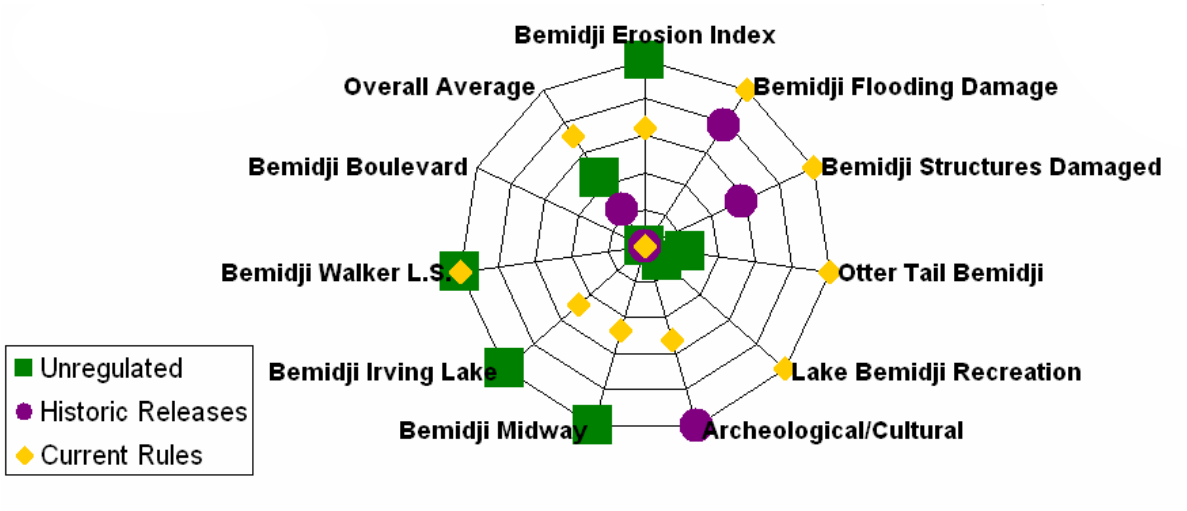



**Figure 2.8: A Radar Diagram**

The radar diagram in Figure 2.8 was taken from the Mississippi Headwaters reservoir re-operation study. The DST for that study contains a similar radar diagram for each reservoir included in the study. The graph above summarizes the performance of three plans against the performance metrics for 11 planning objectives relevant to one reservoir, Lake Bemidji. The radar diagram is like a bull's eye target—the closer to the middle the better. Like the scatter diagram in Figure 2.7, the radar diagram is intended to provide an overall impression of plan performance—in this case, for impacts at one particular lake.

## Normalizing Results

To use a radar diagram or any other display of multiple objectives, it is usually necessary to normalize the different metrics onto one common scale. For example, represent the worst plan with a zero, the best plan with a one, and then scale the other plans proportionally between zero and one. Table 2.4 displays an example of normalization. While normalization is a useful tool in creating multi-objective displays, it has to be interpreted carefully. Normalization can exaggerate or underplay the differences between plans. In order to make graphs utilizing normalization more useful, it is often beneficial to display a table of raw (i.e., un-normalized) results next to the graph. The graph will provide the desired visual summary of results while the table can be a reference for checking which differences in performance shown on the graph are actually significant.

**Table 2.4: Example of Normalization**

| Alternative Plans | Habitat Score (Acres) | Normalized Habitat Score | Description |
|---|---|---|---|
| Plan A | 127 | .70 | *70% between worst and best* |
| Plan B | 109 | .39 | *39% between worst and best* |
| Plan C | 140 | .93 | *93% between worst and best* |
| Plan D | 87 | 0 | *The worst* |
| Plan E | 144 | 1 | *The Best* |

## *2.3 Using Forms to Make Graphs, Charts and Tables Dynamic*

Microsoft Excel has built in tools, called "Forms" that can be used to make graphs and charts (and spreadsheets in general) interactive. The user can change settings and as a result graphs, tables or other features will change automatically. These settings can include choosing which plan(s) is displayed on a graph and which objectives or measures are displayed. The tools utilized most often include list boxes, combo boxes, buttons, scroll bars, check boxes, and option buttons. Table 2.5 summarizes the functionality of each.

**Table 2.5: Excel Forms Useful for Dynamic Graphs, Charts and Tables**

| Form | Example | Functionality |
|---|---|---|
| Drop Down Menu |   | Provides a list of options from which the user can select. A **List Box** provides basically the same function. |

| | | |
|---|---|---|
| Check Box |  | Used to make Yes/No type selections, such as whether to display results for a particular alternative. |
| Option Buttons |  | Option buttons usually appear in groups and are mutually exclusive, i.e., only one option button within a group can be selected. |
| Scroll Bar |  | Incrementally changes the value of a parameter, such as a weight or a discount rate. |

Each of the Forms described above can be set up to change in some way the data displayed in a table or the data used in a graph. The Forms link directly to cells in the spreadsheet that you specify. Using the Form—e.g., making a selection in a drop-down menu or checking a check box—changes the value in the cell linked to the control. Then you can use various formulas in Excel to make the value in the linked cell change the data shown in a table or graph. (Note that these forms do not change the underlying data, they simply change what is displayed in a graph or table.) There are probably dozens of ways this can be done. A few examples are discussed below and some details on how to make forms work are given in Tutorial #3.

Forms are useful for a variety of reasons. There may be too many alternatives (or too many metrics) included in a study to show in a table all at once. The table can be made dynamic by allowing the user to select which alternatives (or metrics) they want shown in the table. A table can also be set up so that a user can select how the metrics in a table are calculated. For example, the user can select the discount rate to be used and the table will change dynamically depending on which rate is selected. This allows for interaction, experimentation and sensitivity analysis.

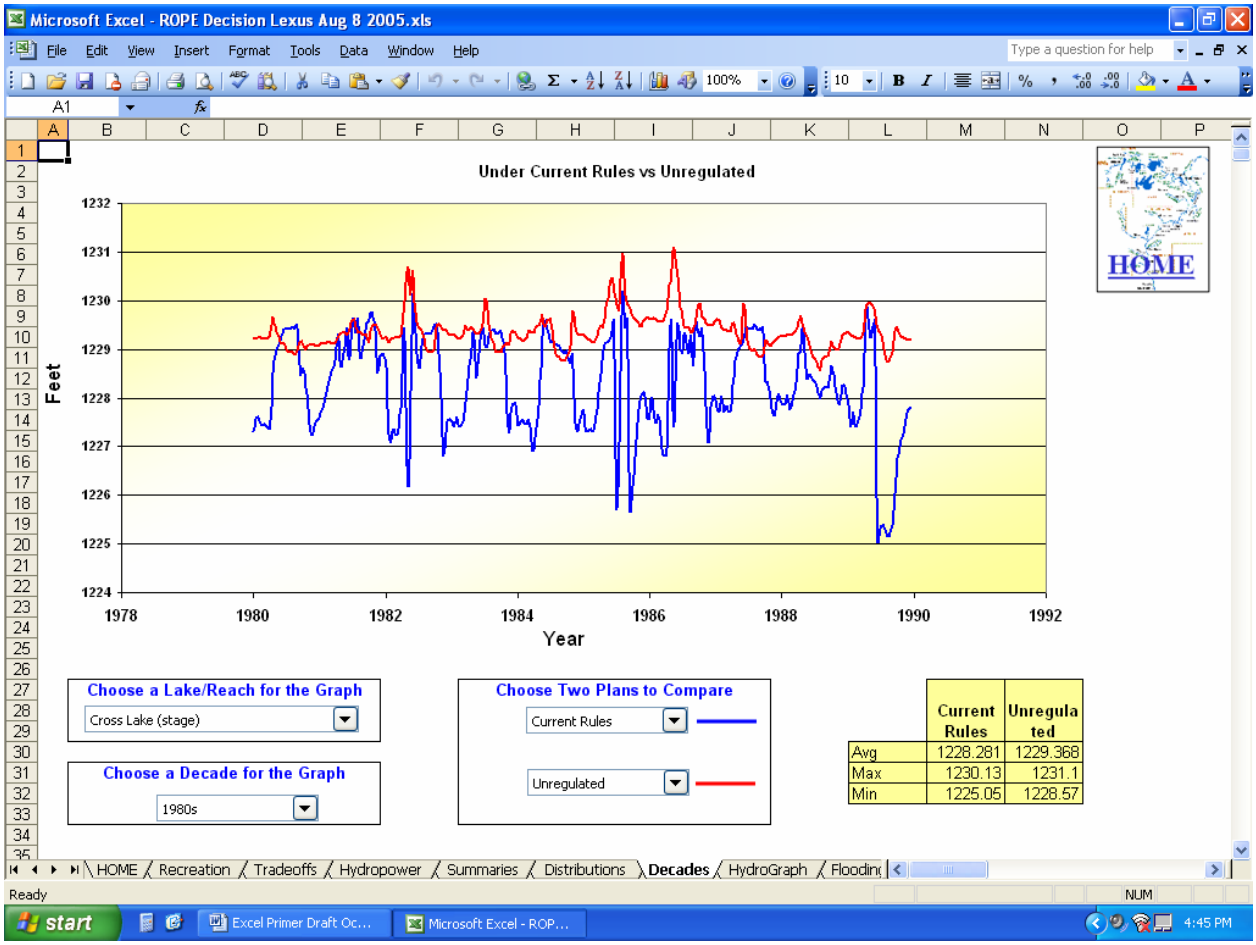



**Figure 2.9: Combo Boxes Making a Graph Dynamic**

Figure 2.9 shows a portion of the DST for the Mississippi Headwaters study. This graph is simply a hydrograph of two different alternatives. But there are four combo boxes (i.e., drop down menus) that drive the data shown on the graph. The user can select 1) the location (lake or reach of the river), 2) the two alternative plans to graph and 3) the decade of the simulated historical record to show. For example, suppose an environmental expert is interested in having a reservoir operation plan that causes very low levels on a particular lake during dry segments of the historical record. They can select the decade in which they expect to see these low levels, the relevant lake, and two alternatives to compare on the graph. The graph changes immediately (or within a few seconds, depending on how big the DST is) and shows the desired "slice" of data. In Figure 2.9, the current operational rules ("Current Rules") are compared to the unregulated condition at Cross Lake for the 1980s segment of the historical simulation.

Figure 2.10 demonstrates a list box and check boxes. The graphs are similar to those shown in Figure 2.7—they show normalized scores on multiple metrics—but the details are beyond the scope of this description. The Forms along the upper portion of Figure 2.10 control the data shown on the graphs. In the upper left corner is a list box where the alternative being graphed can be selected. To the right of the list box, there is a collection of eight check boxes.

The check boxes in the orange box allow the user to select which impact categories (environmental, hydropower etc.) to show on the graph. The check boxes to the right allow the user to select which of two regions (above the dam and below the dam) to graph. In Figure 2.10, the plan "Orig. IS" is selected, three impact areas are selected, and both above and below the dam are chosen.

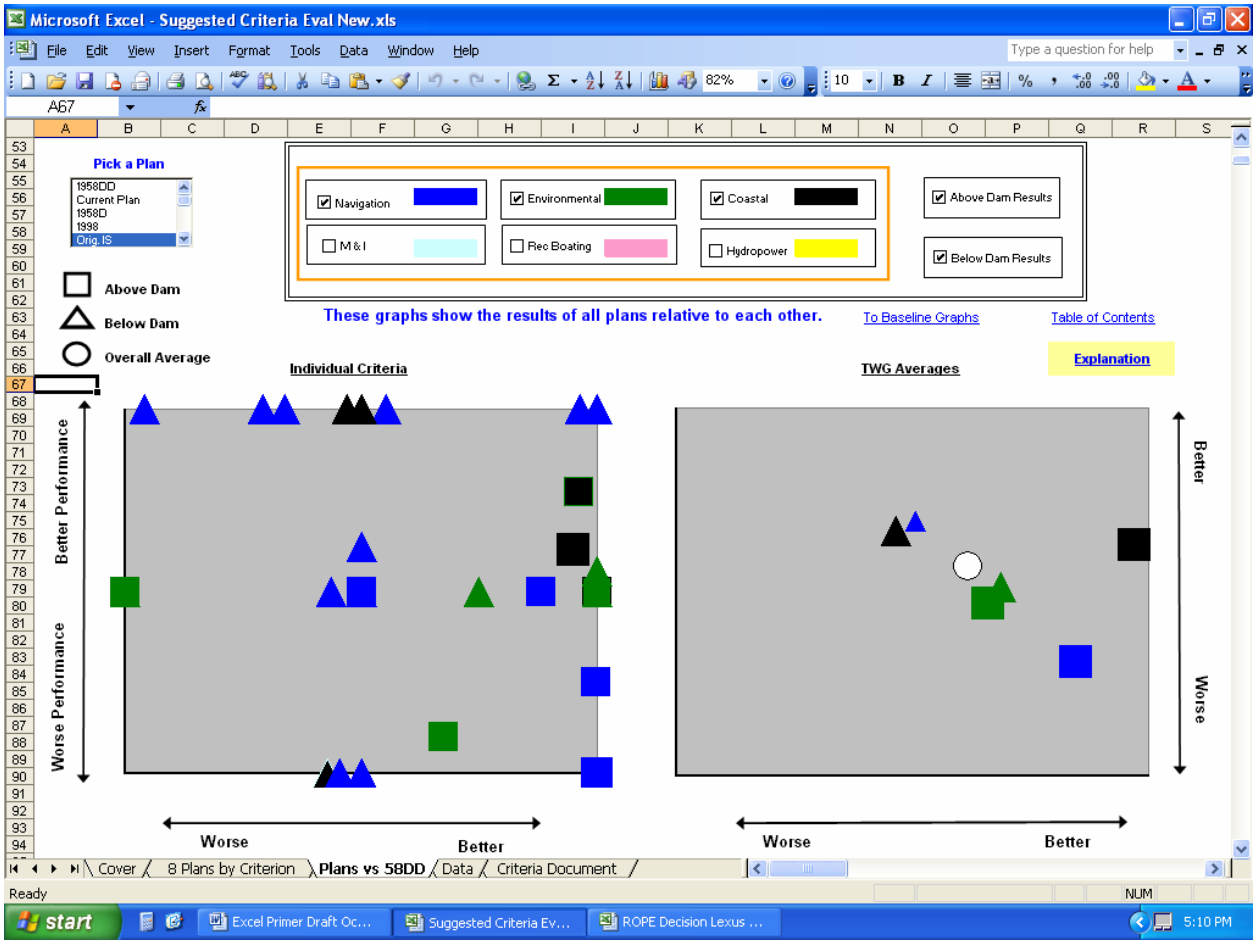



**Figure 2.10: List Boxes and Check Boxes**

## *2.4 Embedding Documents and Slides*

Excel allows you to "embed" Word documents and PowerPoint files within a workbook. The embedded Word or PowerPoint files appear as icons on the spreadsheet where they are placed. The user double clicks on the icon to open and view the file. These features can help organize documentation and can help make the DST more self-explanatory. In the two current studies using DSTs, the tools were distributed among large numbers of people, usually electronically (email, FTP sites etc.). Further, many of the DST users were not always involved

in the technical aspects of the study. Embedding documentation and instructions within the DST helped facilitate successful use of the tool among the diverse groups who received it.

For example, in several DSTs developed for both studies mentioned in this report, Word documents were embedded to provide documentation on the alternatives that were developed, the metrics used for evaluation and other background information. With the documentation embedded in the DST, it becomes a stand alone tool for "one stop shopping" regarding information about the study. The DST contains both data and analysis of data, but also background information that provide essential context for the technical results.

In addition, PowerPoint slides can be used to provide instructions and tutorials regarding the DST. Embedded PowerPoint files can be set up so that when a user opens the file, it automatically starts up as a "slide show" and when the slide show is completed, the user is automatically returned to the DST. Embedded PowerPoint files have been used to deliver general background on the tool, information on changes to the tool, and detailed tutorials on how to use the tool. The advantage of using PowerPoint slides to give instructions on DST use is that it can be done visually using screen captures of the DST itself. For example, Figure 2.11 shows a PowerPoint slide with a screen capture from a DST, and various explanations of what appears in the screen capture.

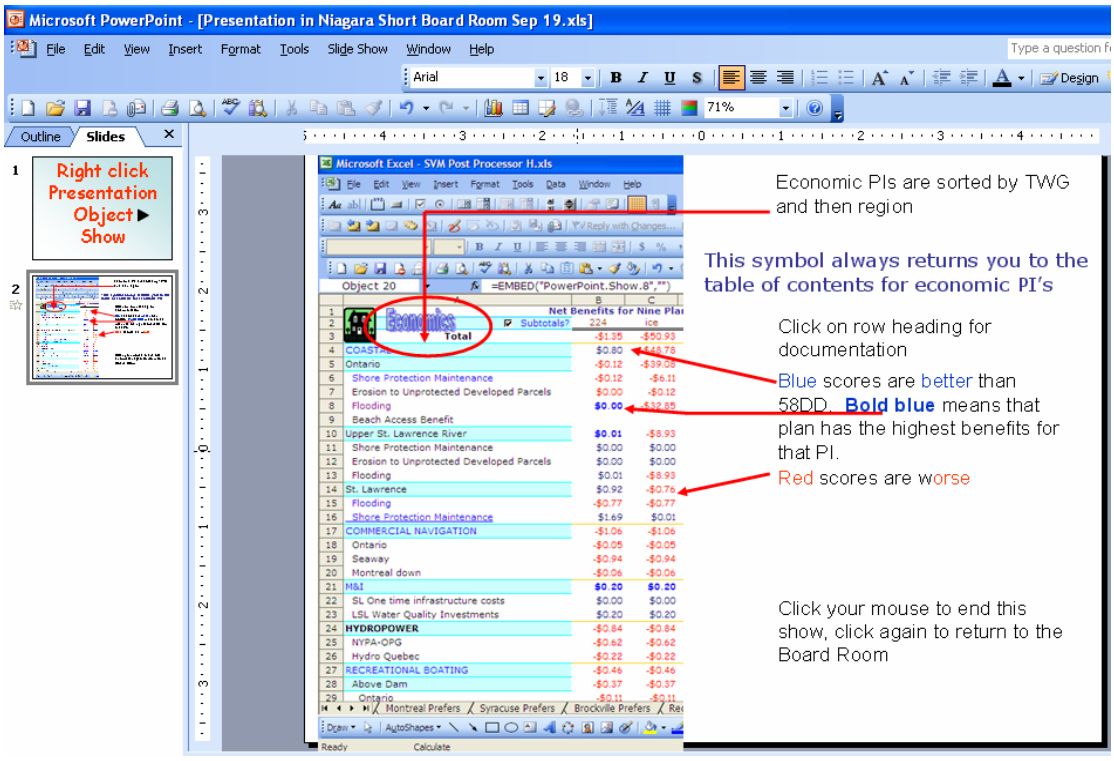



**Figure 2.11: A PowerPoint Slide Explaining the Contents of a DST**

## *2.5 Using Hyperlinks to Facilitate Navigation*

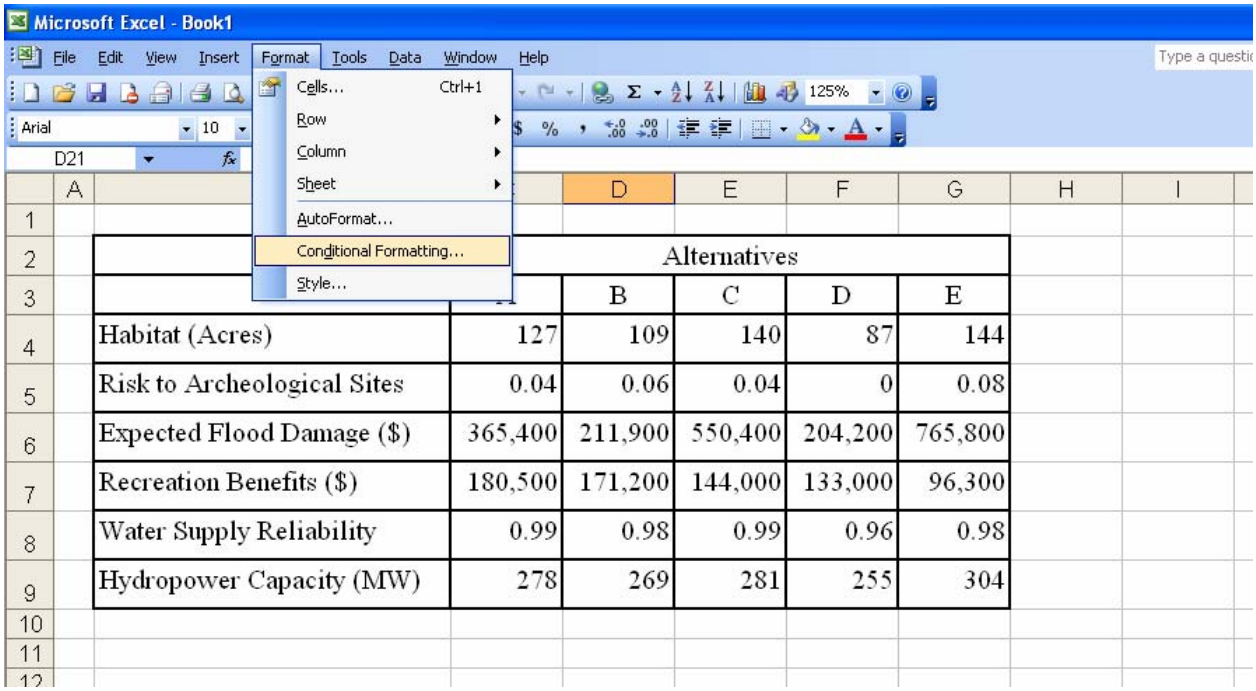
The DSTs used in the studies described earlier contain many worksheets and most of those worksheets have several sections that are meant to be viewed separately, one at a time. Typically, navigation within an Excel workbook is accomplished by clicking on the desired worksheet at the bottom of the screen and then scrolling up and down to find the desired section of a worksheet. DSTs can be very big and navigating such large workbooks in this way is slow and cumbersome. So, the DSTs were constructed like a website—navigation around the DST is accomplished by clicking on various hyperlinks which take the user to specific "pages", each of which contains specific information and displays (e.g., hydrographs might be on one page, economic impacts to one sector might be on another page etc.).

For DSTs that have more than 3 or 4 pages, it is useful to have a table of contents page. This table of contents page will have links to most, if not all, of the other pages and may also have some of the explanatory documents embedded. If a DST is very big, it may be useful to have multiple table of contents pages. In this situation, a main table of contents would link to other table of contents pages that would be organized around specific themes.

# Section 3: Tutorials

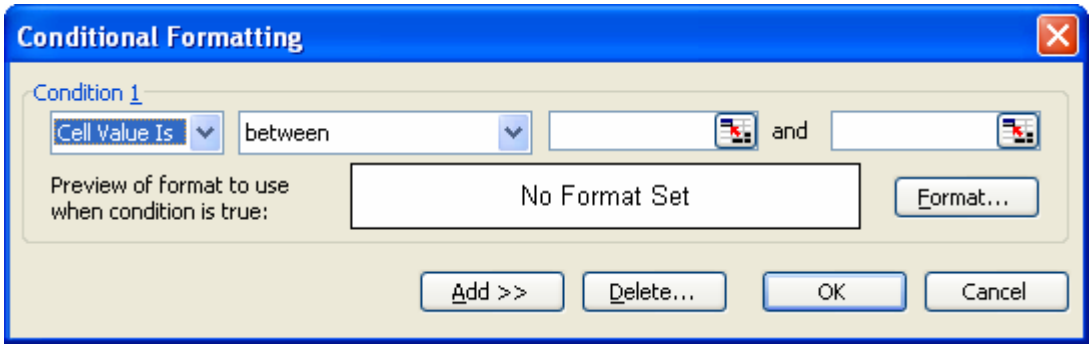
***Tutorial #1: Using the Conditional Formatting Feature in Excel***

*The Conditional Formatting feature can be selected under the 'Format' menu.*




| | Alternatives | | | | |
|---|---|---|---|---|---|
| | | B | C | D | E |
| Habitat (Acres) | 127 | 109 | 140 | 87 | 144 |
| Risk to Archeological Sites | 0.04 | 0.06 | 0.04 | 0 | 0.08 |
| Expected Flood Damage ($) | 365,400 | 211,900 | 550,400 | 204,200 | 765,800 |
| Recreation Benefits ($) | 180,500 | 171,200 | 144,000 | 133,000 | 96,300 |
| Water Supply Reliability | 0.99 | 0.98 | 0.99 | 0.96 | 0.98 |
| Hydropower Capacity (MW) | 278 | 269 | 281 | 255 | 304 |

*Once the feature is opened, you get the conditional formatting dialog box*

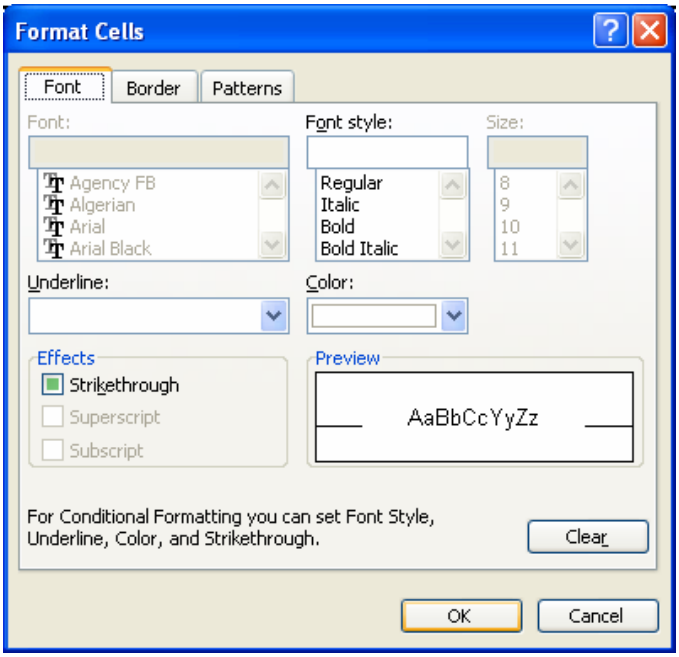



➢ *The first drop down menu in the dialog box allows you to choose whether the conditional formatting references a cell value or a formula within the cell. Referencing the cell value has more use here so we will leave the option as "Cell Value Is."*

- *The second drop down menu allows you to choose the type of condition—e.g., between, greater than, less than, greater than or equal to etc.*

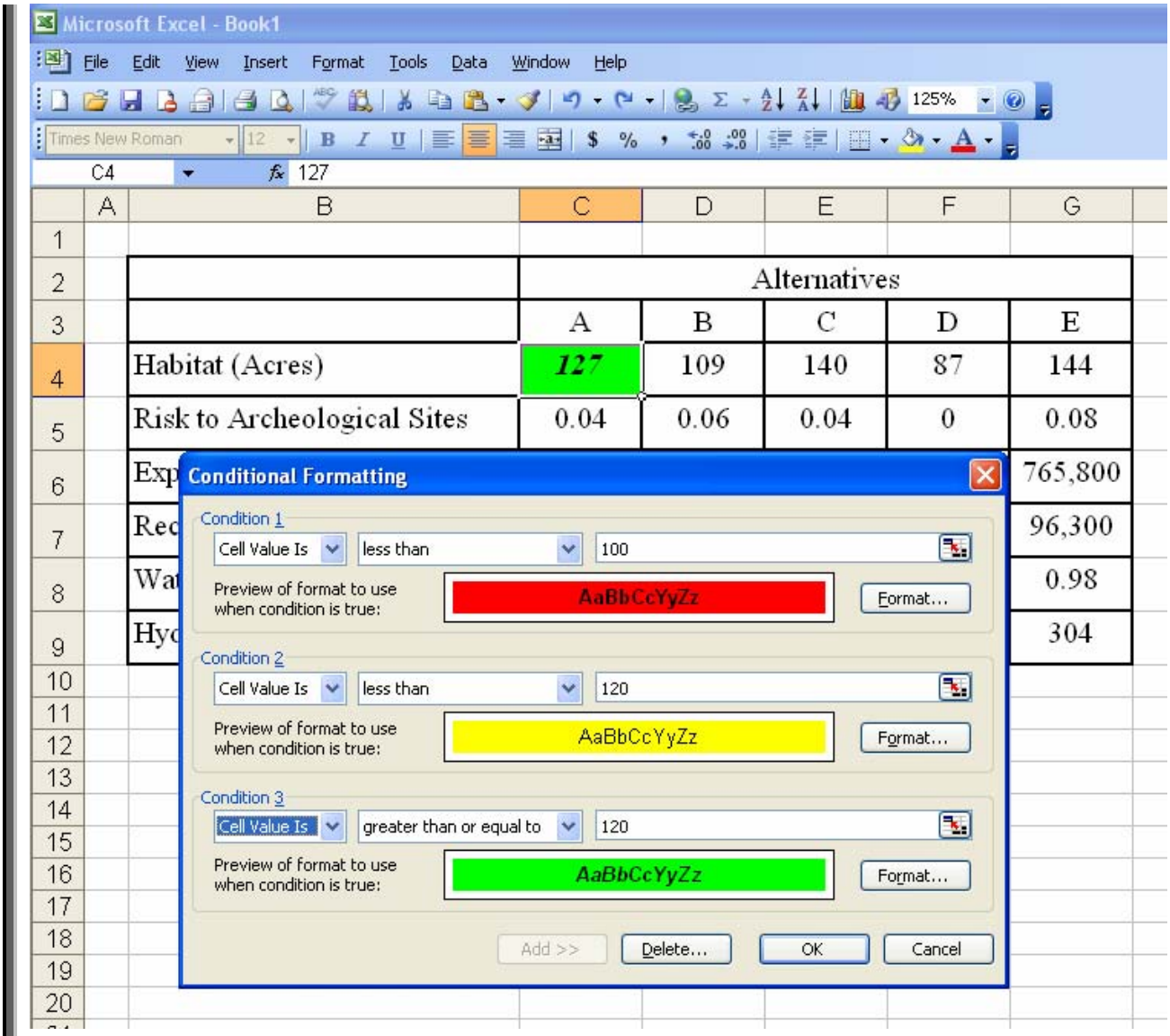
- *Depending on which condition is selected, there will be one or two input boxes for arguments of the condition. For example, with "Between" selected in the graphic above, the dialog box has two boxes for arguments: one to specify the lower bound of the range and one to specify the upper bound of the range. You can either enter a number here or click on the*  *button to enter a cell reference. If you enter a cell reference, then the value in that cell (which can be calculated according to a formula) is the argument for the conditional formatting. You can also enter a formula (instead of a number or a cell reference).*

- *To the right, there is a button that says 'Format.' Clicking on this opens another dialog box which contains all the formatting options. This is where the type of automatic formatting is selected. There are a lot of options: fonts, bold face, italics, font color, borders, shading etc.*




- *Excel allows up to three conditional formats in any one cell.*

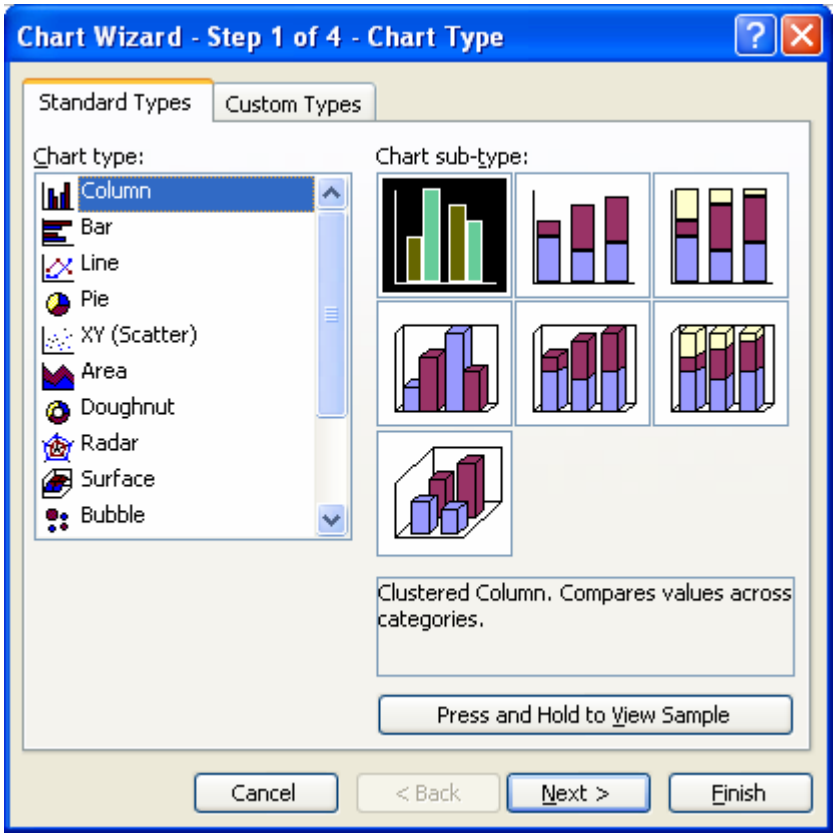
- *The following example shows three conditional formats set for one cell (C4) in a copy of Table 2.2 presented in Section 2. If the value in C4 is less than 100 then the conditional formatting shades the cell red and makes the font bold faced. If the value is less than 120, then the cell is shaded yellow but the font is not changed. If the value is greater than or equal to 120 then the cell is shaded green and the font is changed to bold italics. Excel applies them in the order they are set, so if the value is less than 100 and 120, the first format (red shading, bold faced) gets applied.*




**<u>Shortcut</u>: Especially when working with a big table, it can be time consuming to enter these conditional formatting options over and over again. Excel has a shortcut. Immediately after finishing with the conditional formatting for the first cell, highlight all the cells that will need the same formatting and then either hit <Ctrl> and "Y" or, in the 'Edit' menu, select "Repeat Conditional Formatting". This automatically applies the same conditional formatting to all the highlighted cells. E.g., You could use that shortcut for all the habitat scores in the table above. But be careful with the dollar signs! Dollar signs in Excel formulas keep prevent Excel from automatically changing the cell references when formulas are copied to other locations on a spreadsheet and they automatically appear in formulas entered into the conditional formatting dialog box. When using this shortcut, remember to remove the dollar signs if needed. Check the conditional formatting for other cells after using the shortcut to make sure the cell references were copied the way you intended.**

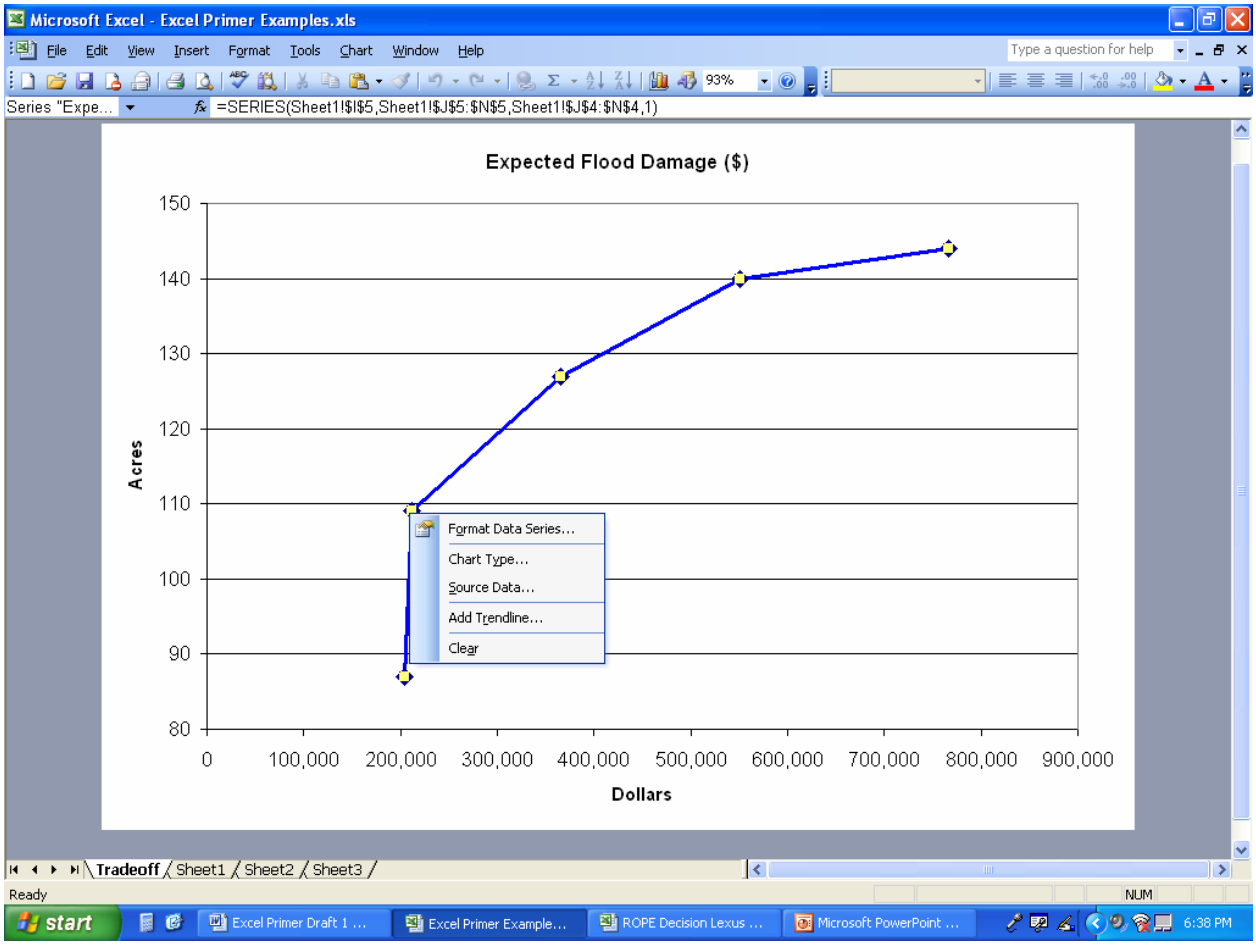
***Tutorial #2: Selecting and Customizing Graphs & Charts***

*Graphs can be inserted by clicking on the graphs and charts button*  *on the Excel toolbar or by opening the 'Insert' menu and selecting 'Chart'. The following dialog box will open.*

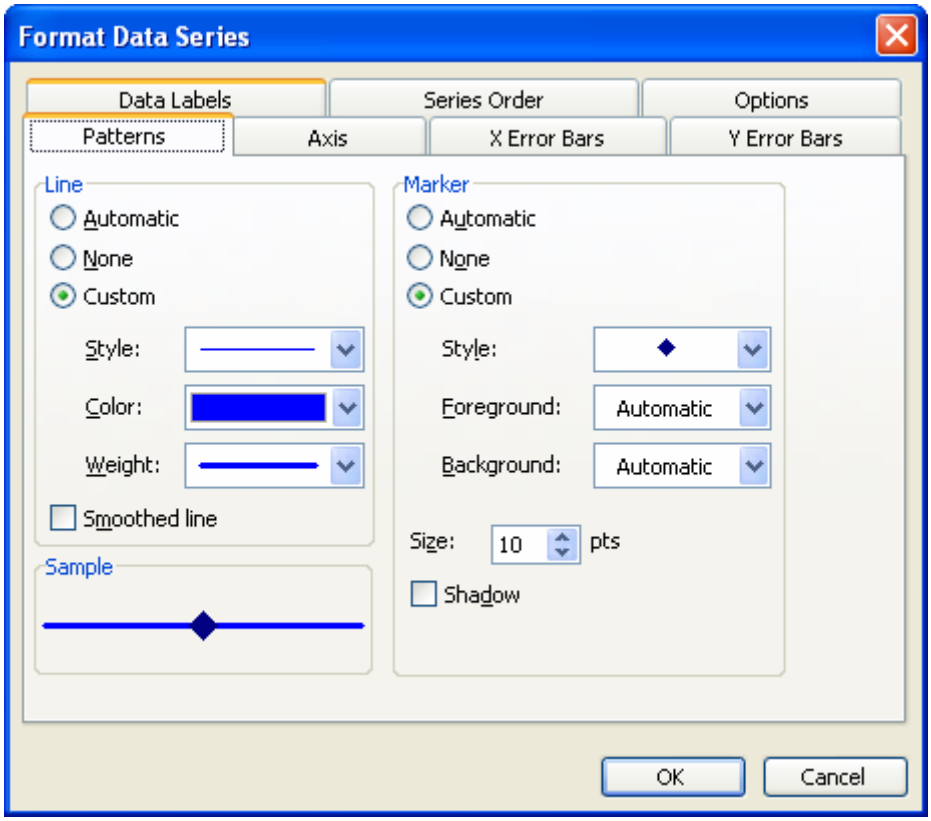



*Within this chart wizard dialog box, you can select the type of graph, insert references for the cells that contain the data you want to graph and add other features such as labels .*

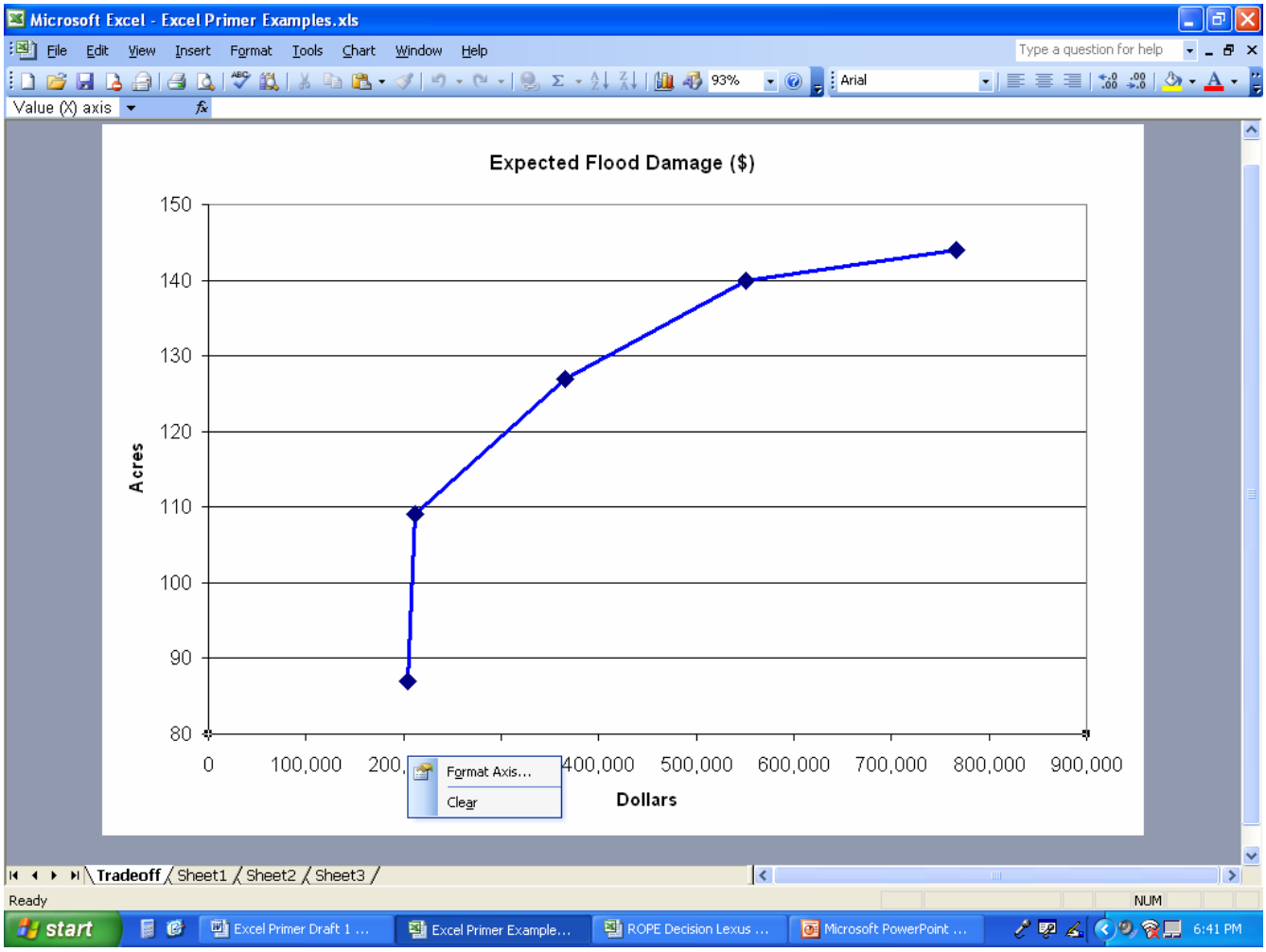
*There are several ways to customize a graph. To customize the bars, lines, or points on a graph, highlight the data series, right click and choose 'Format Data Series'.*




*The following dialog box appears, which allows you to set colors, sizes, shapes, line thickness, series order (i.e., which one appears on top), data labels, and other features.*

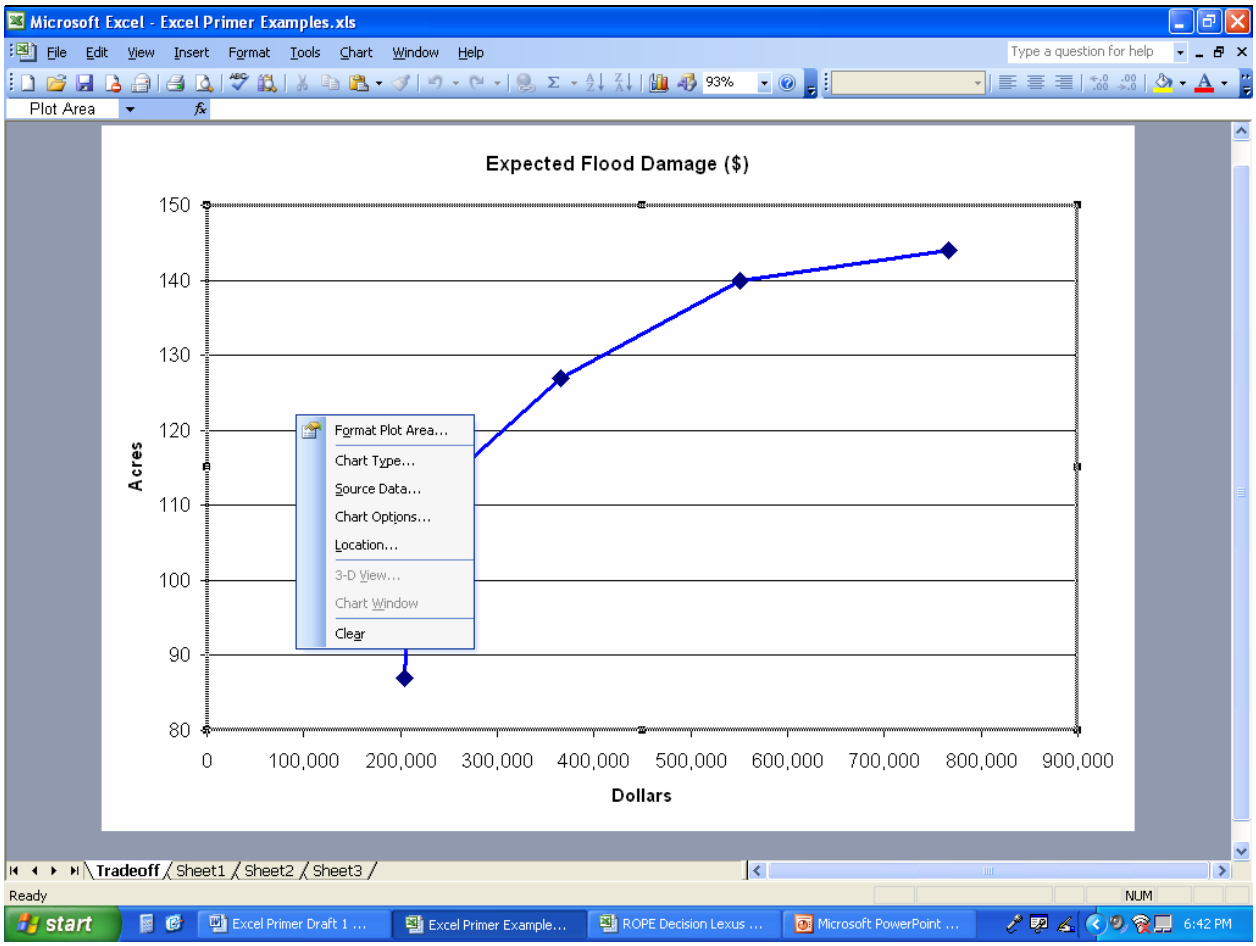



*You can also customize the axes on a graph by right clicking on the desired axis.*




*This allows you to set the scale, format the labels, set the interval between lines and other features.*

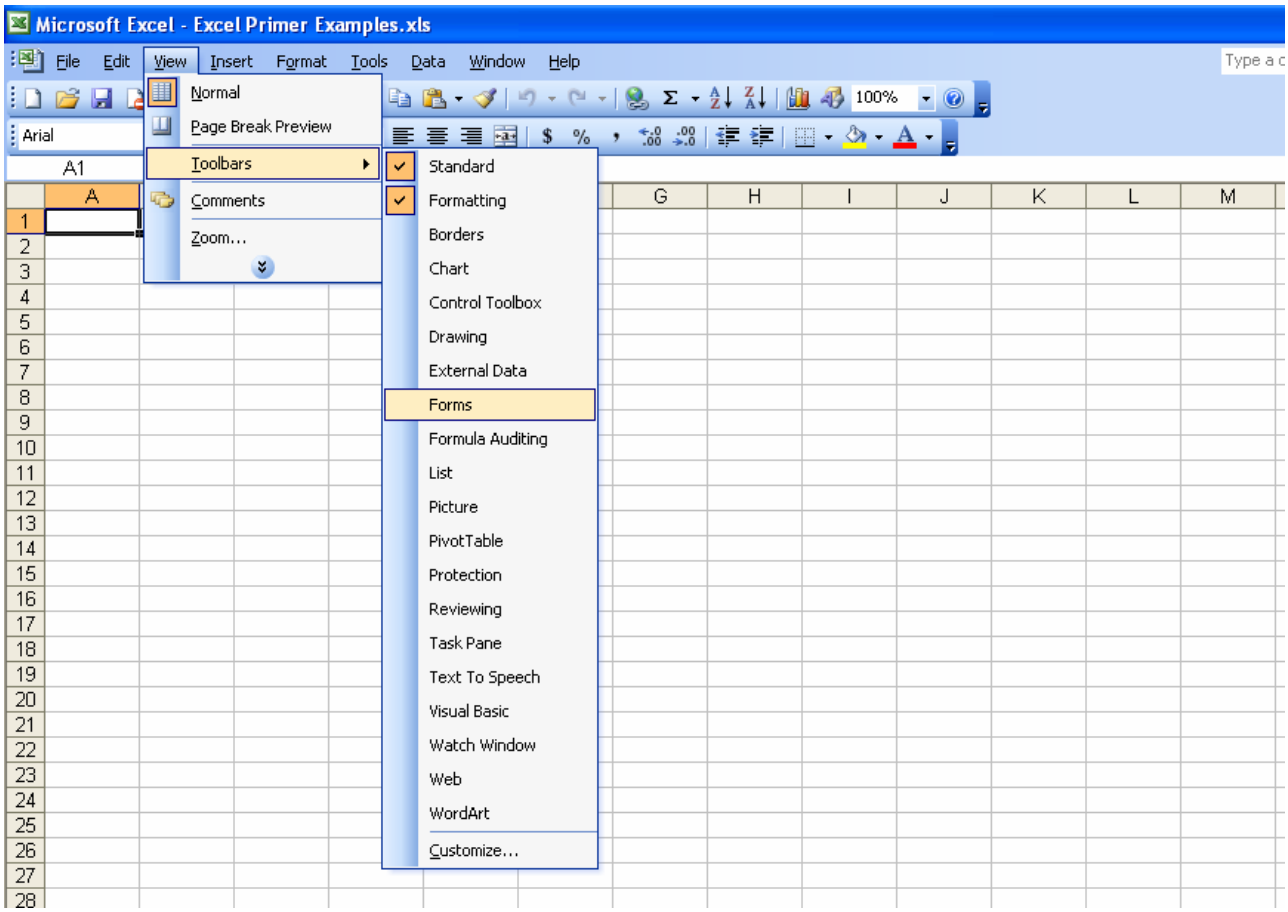
*You can also customize the appearance of the plot area by right clicking there.*




*This allows you to change formatting such as colors and borders. You can also insert a picture to use as the plot background.*

***Tutorial #3: Setting Up Controls in Excel***

*The best way to access the Forms available in Excel is to open the Forms toolbar. Go to 'View', 'Toolbars' and select 'Forms'*




*This will open the Forms toolbar*


*There are several Forms that appear on the toolbar but are not discussed here. However, all of the Forms described above do appear on the toolbar.*

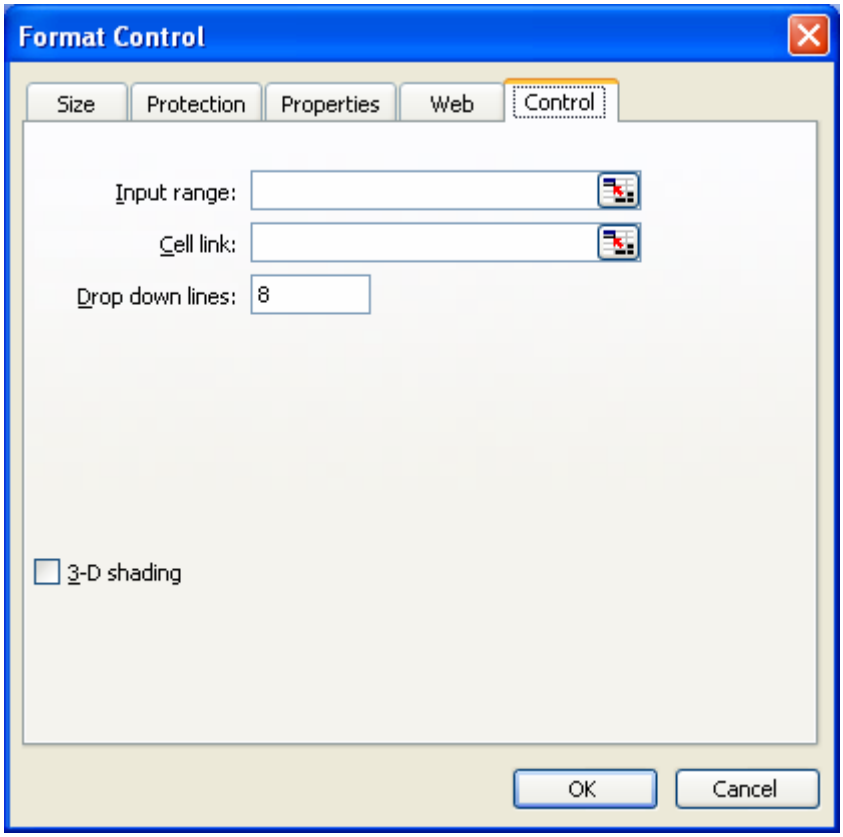
*To place a form on a worksheet, simply click on the appropriate button on the toolbar and then click where you want the form to appear in the spreadsheet. Once placed on the worksheet, the Form can be moved and resized.*

*Once placed on a worksheet, you have to link the control to a graph or table. The first step in doing that is to set the Form's properties. Right click on the Form and choose 'Format Control'*

*which will open a dialog box. The Control Tab within the dialog box is of most interest. Each Form has different options in its dialog box. The options for each Form and the process for utilizing them in making graphs or tables interactive is summarized below.*

## Working with a Combo Box

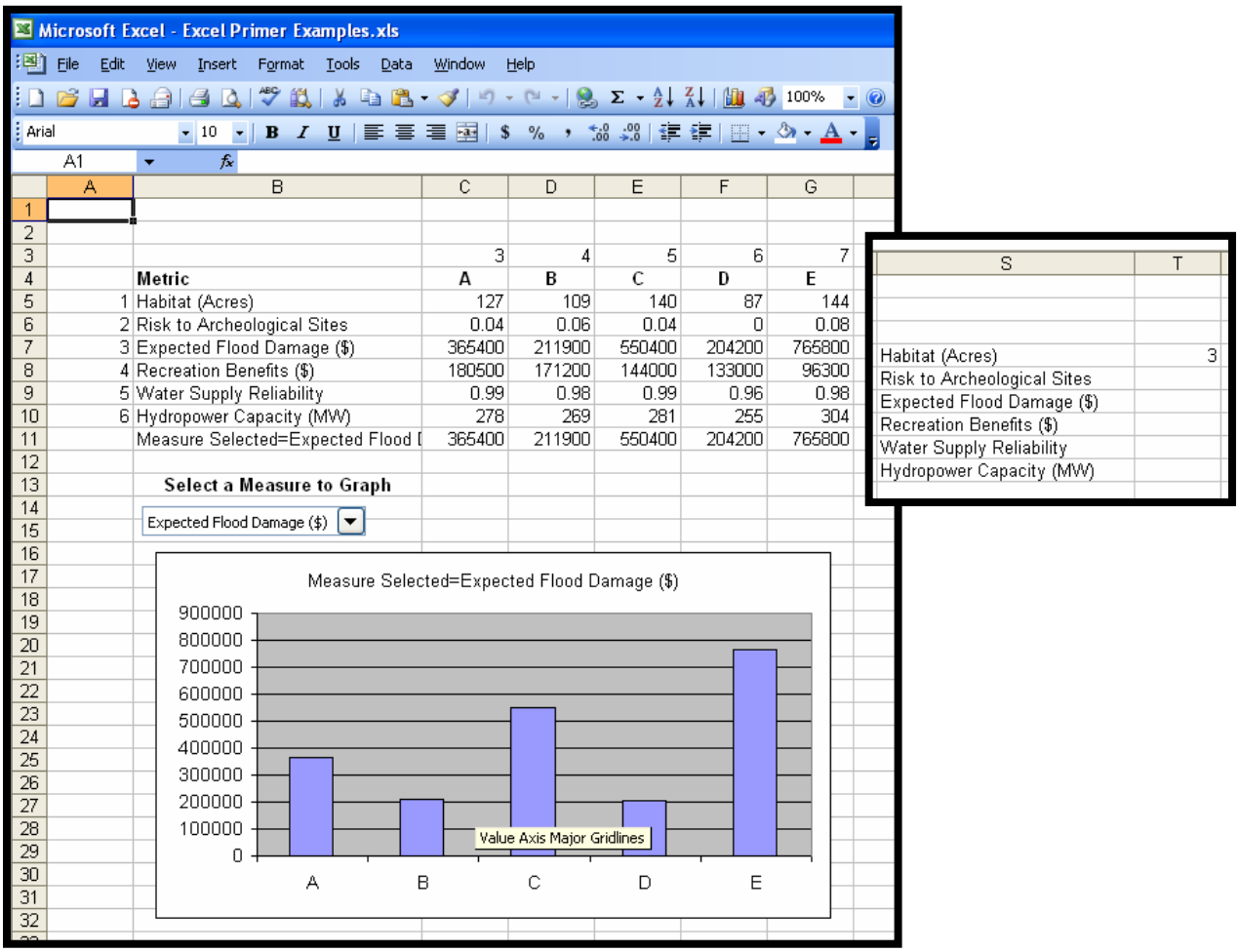
*The dialog box for a Combo Box looks like this.*




*There are essentially three settings you have to work with:*

- *Input Range – this is where you specify the values that will appear in your combo box as options to be selected. Create the list of values somewhere on your worksheet, usually away from the area that will be viewed by DST users, and then click on*  *to specify the cell rang containing the list.*
- *Cell Link – this is the output of the control. When a DST user makes a selection, Excel changes a number in the linked cell. If the 3rd item from the list is selected, Excel puts a "3" in the linked cell. Again, click on*  *to specify the cell.*
- *Drop down lines—sets how many lines appear when the Combo Box menu is opened by a DST user.*

*The value that Excel enters in the linked cell must then be used in some combination with formulas so that it will drive the data show in a table or graph. For example, suppose we wanted to make a bar graph of Table 2 that would show only one measure at a time for all five plans. We could put in a Combo Box that would allow the user to select which measure is graphed. A simple version of the spreadsheet might look like this:*



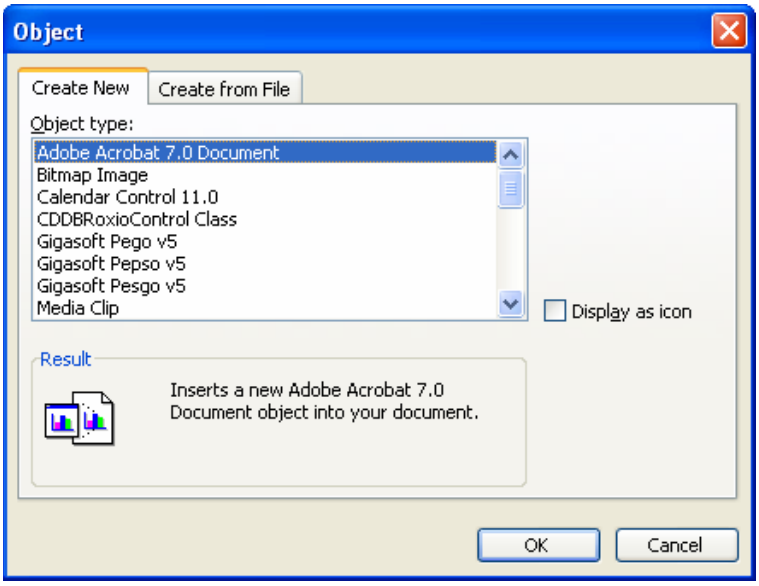

*The data shown in the box to the right are the inputs and output of the Combo Box (these are usually placed off to the right on the spreadsheet where they will not be seen by the user). Column S contains the names of the metrics and cell T4 contains the number corresponding to the metric selected (i.e., the 3rd metric in the list, Expected Flood Damage, is selected). Rows 5 through 10 contain the raw data. The data in Row 11 change as a function of the selection made in the drop down menu using Excel's "Vlookup" function. If a different metric is selected in the Combo Box, the value in cell T4 will change, and the vlookup functions in cells C11: G11 will return the appropriate values. The bar graph is set to utilize whatever values appear in row 11, so when the metric selected in the Combo Box is changed, the graph will change. Note that other excel functions, such as the "If" function, can be used to change the data in row 11 as a function of the selection in the Combo Box. The example shown above is provided on the Tutorial CD so you can see exactly how the vlookup functions work.*

**Working with Other Forms**

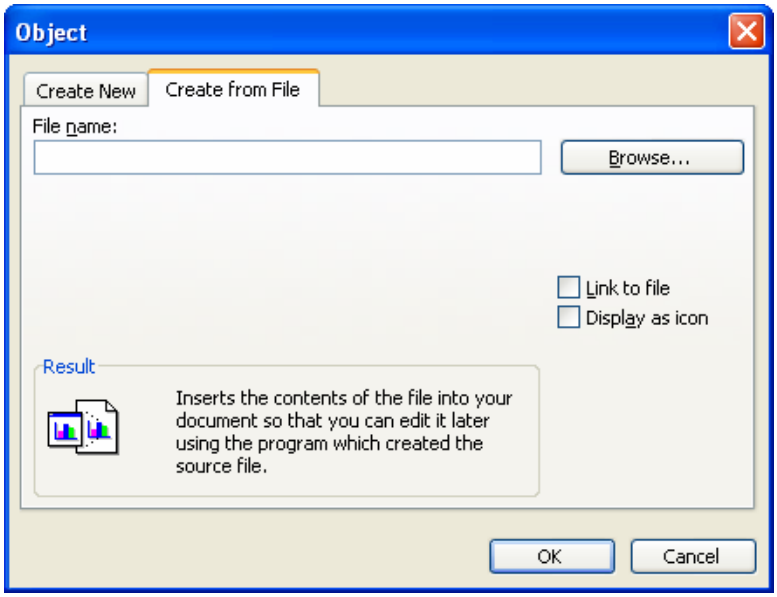
*The basic setup described for a combo box is also needed for the other forms available in Excel. The general idea is to have a Form control the value in a particular cell. That cell is then used in various formulas which select or manipulate data that is shown in a table or on a graph. The Tutorial CD includes a number of sample DSTs, each of which includes various examples on how to use each kind of form.*

***Tutorial #4: Embedding Word and PowerPoint Files***

*Embedding word and PowerPoint files is fairly simple in Excel. The first step is to create the file you want to embed. Once that is done, in your Excel DST, navigate to the page where you want the object to appear and then click on 'Insert' and select 'Object' to open the following dialog box.*



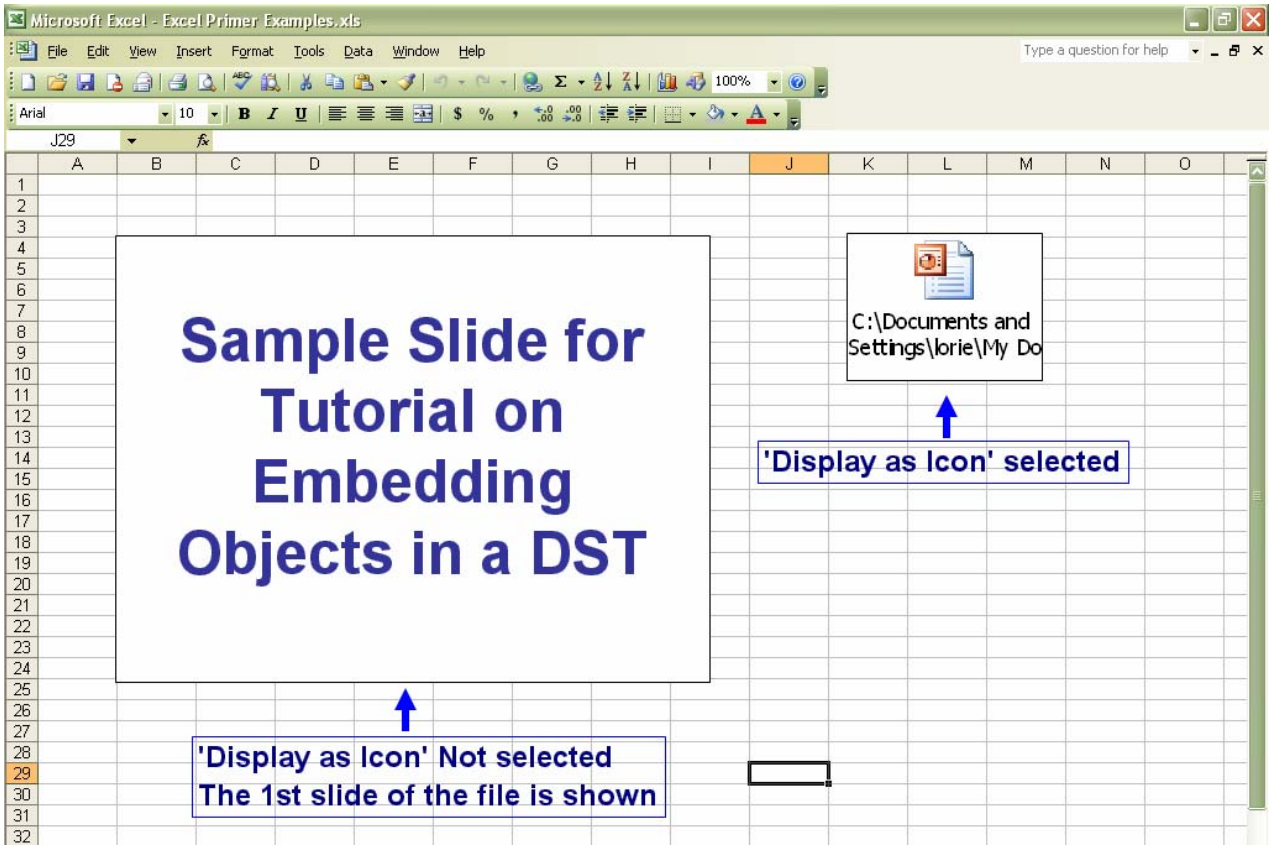

*The dialog box opens in the 'Create New' mode, which allows you to create a new file and embed that new file. We want to embed an existing file, so click on the 'Create from File' tab near the top to get this:*



*Click on the 'Browse…' button to find the file you want to embed. That will open the standard Windows file browsing dialog box. Once you select the file, it's path and name will appear in the dialog box shown above. There are two other options: 1) Link to file and 2) Display as Icon.*

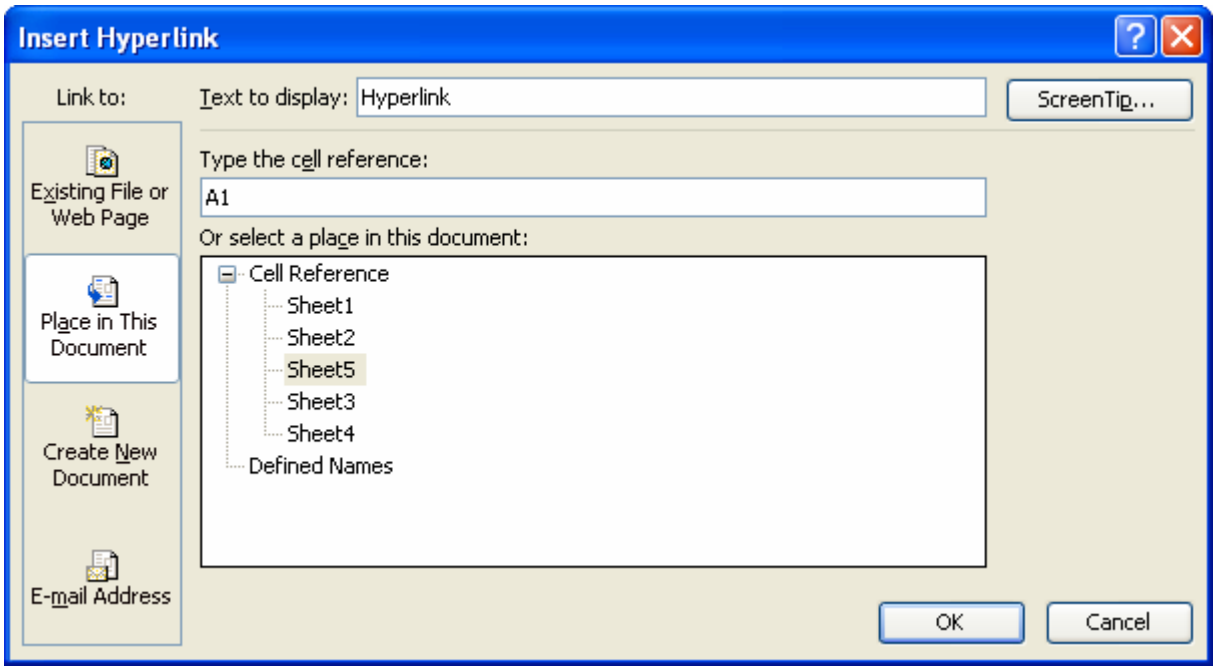
*The Link to file option means that whenever the source file is changed, those changes will be reflected in the version embedded within your DST. We have rarely selected this option because the DSTs are shared among so many people working on different computers and networks that the link to the original source file is not valid.*

*Selecting the Display as Icon option does exactly that—the embedded file will appear in your DST as an Icon, such as the typical MS Word Icon. If this option is not selected, the embedded object will appear as itself in the DST. For example, an embedded Word document will appear as the first page of the document itself; an embedded PowerPoint file will appear as the first slide. These are illustrated in the figure below.*



***Tutorial# 5: Creating Hyperlinks in Excel***

*The first step to create a hyperlink in Excel is simply to put in the text for the actual hyperlink somewhere on the page. Once this is done, right click on that cell containing the hyperlink's text and select 'Hyperlink' from the menu. The following dialog box will open.*




*The dialog box often opens with the 'Existing File or Web Page' option selected. This tutorial will focus on creating hyperlinks for navigating within the DST rather than hyperlinks to external files. Therefore, click on 'Place in This Document' to see the options shown above.*

*The dialog box allows you specify the text to display in the hyperlink (which you may have already typed into the cell, but you can change it here), and the worksheet and cell(s) to be linked. It is a good idea to test the link once you have set it up to make sure it centers the target page when the link is clicked on. To change or delete a hyperlink, simply right click on the link and select either 'Edit Hyperlink' or 'Remove Hyperlink.' The edit option will open the above dialog box again.*